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STUDY OF FERTILIZER UPTAKE USING RADIOACTIVE PHOSPHORUS[1]

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It is well known that the wheat crops of many areas of Saskatchewan show a marked response to the application of phosphate fertilizers. The fertilizer is applied with the seed when it is sown in the spring and an increased yield is usually obtained (10). In Saskatchewan, the amount of phosphorus applied is ordinarily very much less than the amount present in the soil, and it is of considerable interest to know to what extent the fertilizer is utilized and at what period of growth it is taken up most rapidly. It is also interesting to know the relative uptake of soil phosphorus and fertilizer phosphorus at different stages of growth of the plant.

The desired information can be obtained by marking the applied phosphorus by the addition of a radioactive isotope, P^{32}. Radioactive phosphorus has a half life of 14.3 days and emits β particles having a maximum energy of 1.7 mev (14), both characteristics making it very suitable for this type of work (1, 2, 4, 5, 6, 12). The radioactive phosphorus is converted to phosphate and mixed with the inactive phosphate fertilizer. Since the radioactive phosphorus has the same chemical properties as the inactive phosphorus, it will accompany the inactive phosphorus in all its reactions and the path taken by the fertilizer phosphorus can then be followed or traced by the detection of the radioactivity emitted by the radioactive phosphorus, provided, of course, that the fertilizer phosphorus and the inactive phosphorus are initially in the same valence state.

By making quantitative measurements of the radioactivity, the radioactive phosphorus, and hence the inactive fertilizer phosphorus which it accompanies, can be followed quantitatively.

The use of P^{32} as a quantitative tracer for the fertilizer phosphorus is independent of any reaction, exchange or otherwise, which the phosphorus may subsequently undergo.

Suppose, for example that we represent the radioactive $PO_4^{\equiv}$ by a red balls, the inactive fertilizer $PO_4^{\equiv}$ by b green balls and the inactive $PO_4^{\equiv}$ in the soil by c black balls, the balls being indistinguishable apart from their colour. Suppose further that $a \ll b \approx c$ and a, b and c are large numbers (say 10^{10}, 10^{20}, and 10^{20}, respectively). The a red balls and the b green balls are put in Bag I (Fertilizer) and mixed well. The c black balls are placed in Bag II. In any random sample withdrawn from I, the red and green balls are in the ratio a/b and in fact, if we find x red balls in a grab

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sample there will probably be $x \cdot b/a$ green balls accompanying it. With the large numbers suggested above, statistical fluctuations will be very small, *e.g.*, in a grab sample containing one hundredth of the balls in the bag the standard variation is 0.01%[1] (15).

Suppose now that we add the contents of Bag I to Bag II and mix well. This corresponds to adding the labelled fertilizer to a soil containing a certain amount of available phosphorus. There are now $a+b+c$ balls that are indistinguishable while in the bag. If we withdraw a ball, the probability of it being red, green or black is in the ratio $a : b : c$ and if we withdraw y balls, there will probably be $ay/a + b + c$ red, $by/a + b + c$ green and $cy/a + b + c$ black balls. The ratio red/green $= \frac{ay}{a+b+c} \Big/ \frac{by}{a+b+c} = a/b$ as before and correspondingly if we find z red balls in a grab sample, there will be $z \cdot b/a$ green balls accompanying it, *which came originally out of bag I*, plus, of course, some black balls. Thus the number of green balls in a sample may be obtained by multiplying the number of red balls found to be present by the factor b/a. The ratio a/b and hence b/a is known from a knowledge of how many red and green balls were put in Bag I, *i.e.*, how many $P^{32}O_4^{\equiv}$ were added to a given weight of fertilizer. The plant makes no distinction between active and inactive phosphorus, provided both are in a given state of chemical combination, say $PO_4^{\equiv}$, and thus any activity found in the plant can be used as a measure of fertilizer uptake. It will not tell us about the total uptake of phosphorus as this depends also on c.

The case of so-called exchange with the soil does not affect the validity of the above conclusions. Suppose that in a certain time Q atoms out of the added $(a+b)$ fertilizer atoms exchanged with Q soil phosphorus atoms and are thereby converted into a form unavailable to the plant (possibly exchange at the surface of an insoluble phosphate). Then, of the Q exchanging, $\left(\frac{a}{a+b}\right)$ Q will be red balls and $\left(\frac{b}{a+b}\right)$ Q will be green balls and the ratio red/green left is $\frac{a - (a/a + b)Q}{b - (b/a + b)Q} = a/b$ as before. If Q′ subsequently get back into circulation again (by a further process of exchange) the ratio red/green balls will still be unchanged.

Thus the $P^{32}O_4^{\equiv}$ can be used as a quantitative tracer for the inactive $PO_4^{\equiv}$ of the fertilizer.

In this particular study the object was: *(a)* to obtain an estimate of the amount of fertilizer used by wheat plants growing on a particular soil in a given season; (*b*) to measure the percentages of phosphorus taken from the fertilizer and the soil; (*c*) to obtain an indication of the period of growth over which the fertilizer was taken up most rapidly; (*d*) to determine the extent of the movement, if any, of fertilizer phosphorus in the plant during its development. It is hardly necessary to point out that these results could not have been obtained by chemical analysis alone.

[1] Drawing n balls in succession from w in a bag containing pw red and qw green balls, $\sigma^2 = npq \frac{(w-n)}{(w-1)}$. In the above, $w = 10^{20}$, $n = 10^{18}$, $p = 10^{-10}$, $q = 1$ from which $\sigma = 10^4$ or $\frac{10^4}{10^8} \cdot 100 = 0.01\%$. Furthermore, the probability of a sample showing a variation greater than 0.05% is 0.00001.

EXPERIMENTAL

General Procedure

The experiment was carried out under field conditions. The experimental plot was situated in a large field of wheat on the farm of Mr. C. C. Agar at Floral, Saskatchewan. The soil was a solonetzic member of the Elstow Association having a silt loam texture (11). The field had been fallow the previous year. The plot (see Fig. 1) was fourteen feet square and consisted of 17 small plots each one foot in length. Guard rows were sown between each of the rows containing the small plots.

Fifteen of the plots constituted a completely randomized block design of three harvest dates with five replicates. Plots 16 and 17 were carried to maturity and consequently required the application of a higher proportion of radioactive phosphorus than the others.

The plots were sown on April 27th, each plot receiving six kernels of Thatcher wheat. All the plots were fertilized at the rate of 25 pounds per acre with ammonium dihydrogen phosphate, which is the equivalent of the fertilizer of analysis 11-48-0. At the time of seeding it was not possible

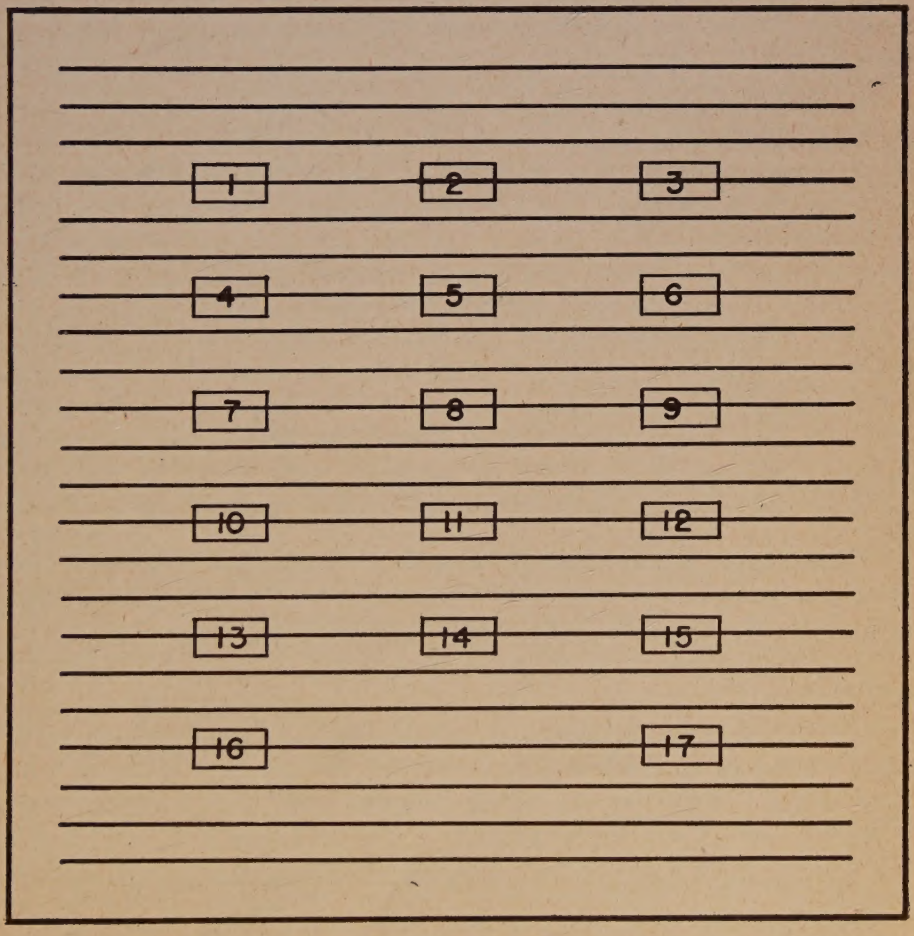

FIGURE 1. Diagram of the arrangement of the experimental plots.

to obtain the fertilizer, with the radioactive isotope incorporated, in a granular form similar to the usual phosphate fertilizer. Because of this, the fertilizer was applied in solution. The fertilizer solution was made by dissolving 2.470 grams of $NH_4H_2PO_4$ in water in a 200 ml. volumetric flask. Thirty ml. of a stock solution of radioactive phosphorus[1] was added and the total solution made up to 200 ml. and well mixed. This fertilizer solution was applied to plots 1 to 15 at the rate of 10 ml. per plot. This gave each plot 0.1235 grams of $NH_4H_2PO_4$, or 0.0332 grams of phosphorus, and an amount of radioactive phosphorus having an activity of 2.82×10^6 counts per minute (on April 27th)[2]. The solution applied to plots 16 and 17 was made by dissolving 0.247 grams of $NH_4H_2PO_4$ in 20 ml. of stock solution of radioactive phosphorus. Ten ml. of this solution was applied to each plot. This gave each plot 0.1235 grams of $NH_4H_2PO_4$ and an activity of 1.88×10^7 counts per minute (as of April 27th).

Due to dry weather early in the season, the germination was not as high as expected. However, the plants tillered well and grew healthily and there were from 4 to 6 plants in each plot. This variation did not influence the results noticeably.

During June and early July, the moisture conditions were good. However, the latter part of July was hot and dry and this hastened the maturing of the grain. The weather conditions for Saskatoon are given by the Dominion Meteorological Report for the months of May, June and July as follows:

	Temperature			Precipitation
	High	Low	Average	
				ins.
May	89	20	49	0.9
June	87	35	58	1.9
July	102	39	67	1.9

The plots were harvested at intervals: five on June 19th, one week prior to shot blade; five more on July 8th at the heading stage, when 50 per cent of the plants had heads showing; five more on July 29th in the early dough stage (grain just beginning to fill) and finally two on August 11th at maturity.

The plants were harvested at ground level and analysed for total phosphorus and radioactive phosphorus according to the methods outlined under "Analytical Procedure". Where possible, the plants were divided into straw and head.

[1] Stock solution consisted of 3.75 mg of P as Na_2HPO_4 dissolved in 100 ml water: total activity approximately 1mc.

[2] The method of measuring the amount of radioactivity by counting it with a Geiger counter is described later.

TABLE 1.—SELF ABSORPTION BY MAGNESIUM PYROPHOSPHATE CONTAINING RADIOACTIVE PHOSPHORUS

Wt. of sample in mgms.	Count ÷ 128	Per cent of Total Count	Correction Factor
0	24.10	100.0	1.000
33.3	23.30	96.7	1.034
50.6	22.58	93.7	1.066
64.0	22.68	94.2	1.060
66.5	23.38	97.0	1.030
79.0	21.84	90.7	1.102
83.4	22.46	93.3	1.072
88.5	21.56	89.5	1.117
114.1	20.78	86.2	1.160
132.2	21.46	89.0	1.123
132.7	21.20	88.0	1.136
150.6	21.16	87.8	1.138
163.1	20.68	85.8	1.165
168.8	20.60	85.5	1.170
177.4	20.32	84.4	1.184
210.3	19.12	79.4	1.260
214.1	21.00	87.2	1.147
227.1	19.82	82.3	1.215

Analytical Procedure

The samples were dried in the oven at 105° C. and weighed. After this, they were wet ashed with nitric, sulphuric and perchloric acids according to the procedure of Brenner and Harris (3). The silica was filtered off and the phosphorus precipitated as phosphomolybdate, then dissolved in ammonia and reprecipitated as magnesium ammonium phosphate according to the method of Piper (13). After centrifuging and washing, the precipitate was transferred to a small weighed platinum dish, 2.2 cm. diameter. The completeness of any operation was checked by testing for residual activity. The precipitate was carefully dried at a low temperature, ignited to pyrophosphate, counted and weighed. The weight of total phosphorus was calculated from the weight of the pyrophosphate precipitate.

Method of Counting

The platinum dish containing the magnesium pyrophosphate precipitate was placed in a machined brass plate and slid under the window of a Geiger-Muller beta chamber having a thin mica window (3 mg./sq. cm.) at one end (see Figure 2). Care was taken to ensure standard geometry. The chamber was connected to a scale of 128 scaling circuit and any given sample was counted for a sufficient length of time to give approximately 10,000 counts (statistical error is then approximately 1%). The background count, usually about 20 per minute, was substracted from the observed count. The decay of the P^{32} can be allowed for in one of two ways:

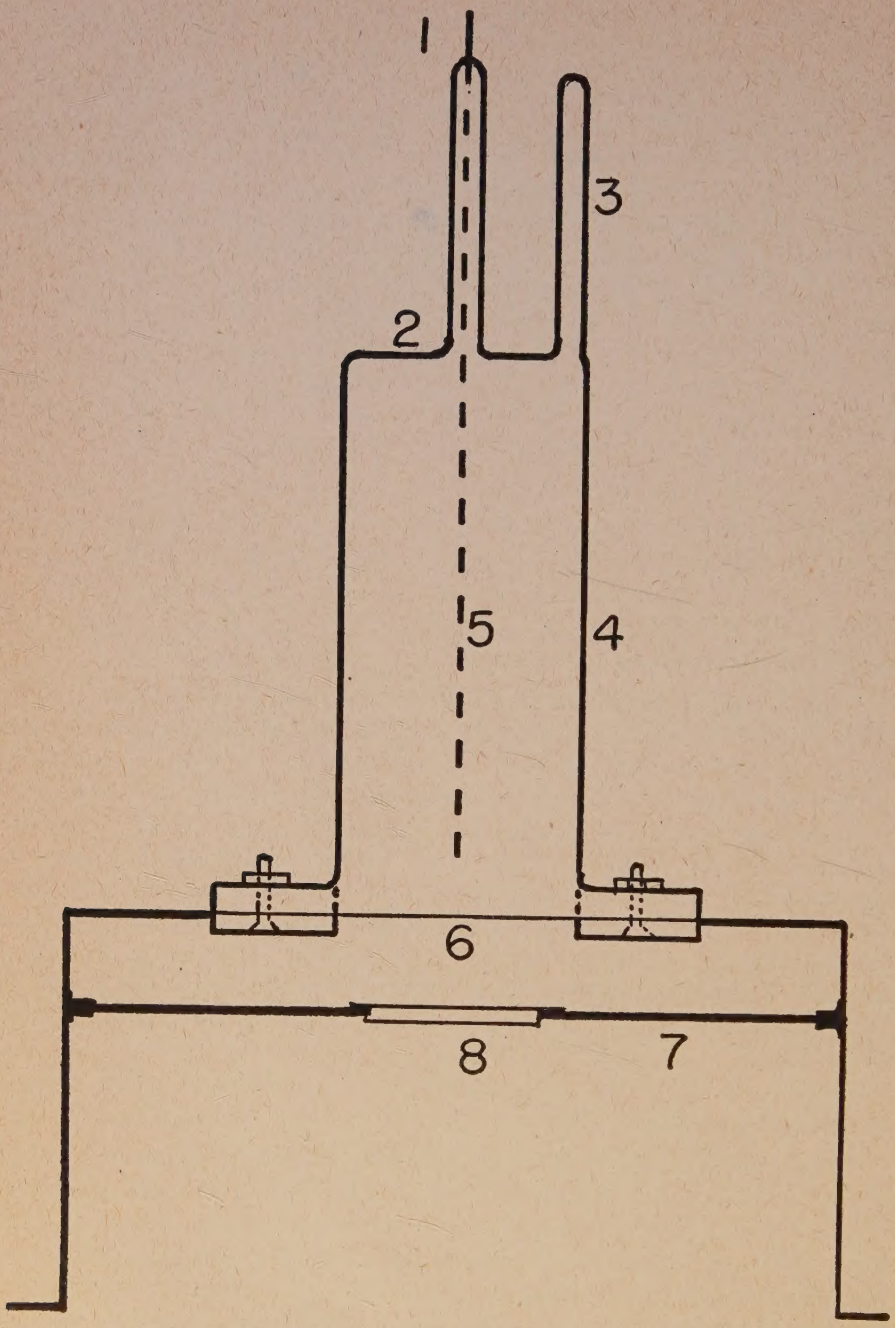

FIGURE 2. Counter Tube—

1. Lead to amplifying system.
2. Glass top.
3. Side tube for filling with argon and alcohol vapour at eight cm. pressure.
4. Cylindrical brass wall.
5. Tungsten wire.
6. Mica window, three mg./cm.^{2} thick and coated with aquadag.
7. Machined brass plate to hold sample dish.
8. Platinum sample dish.

TABLE 2.—FERTILIZER UPTAKE BY WHEAT AT THREE HARVEST DATES

Harvest Date	Wt. of plant material gm.	Wt. of total phosphorus, mg.	Fertilizer phosphorus taken up, mg.	Fertilizer phosphorus taken up, %	Phosphorus in plant coming from Fertilizer, %
June 19 (7½ weeks)	4.1	17.0	3.98	12.0	23.4
	10.3	22.2	5.04	15.2	22.7
	10.3	22.6	3.92	11.8	17.3
	8.5	20.6	4.38	13.2	21.2
	5.1	20.0	4.05	12.2	20.3
Average	7.7	20.5	4.3	12.9	21.0
July 8 (10 weeks)	22.1	47.6	7.97	24.0	16.9
	27.8	71.6	6.74	20.3	9.4
	32.2	44.4	6.74	20.3	15.2
	15.2	53.7	7.04	21.2	13.1
	12.6	36.2	6.91	20.8	19.1
Average	22.0	50.7	7.1	21.3	14.7
July 29 (13 weeks)	25.8	52.8	8.20	24.7	15.5
	21.7	44.9	6.84	20.6	15.2
	54.6	100.6	8.00	24.1	7.9
	48.4	98.1	9.99	30.1	10.2
	53.6	114.0	6.31	19.0	5.5
Average	40.8	82.1	7.9	23.7	10.9

(a) Take an aliquot of the original stock solution, evaporate to dryness on a platinum dish and count it immediately before and after counting the unknown material (*i.e.* "sandwiching "the unknown). The aliquot of the original thus serves as a standard and eliminates the necessity for correcting for the decay of the P^{32} or for small fluctuations in the counter.

(b) An aliquot of the stock solution can be compared with a uranium standard (actually uranium oxide mounted on a suitable plate) at the beginning of the experiment. Thereafter, the uranium standard is counted before and after each count of an unknown sample. By calculating back to the value of the standard in the first experiment, counter fluctuations can be eliminated. The decay of P^{32} can be allowed for mathematically, knowing the half life of P^{32} (14.3 days) and the time elapsed since the beginning of the experiment.

If the sample has any appreciable thickness it is necessary to allow for the absorption of beta particles by the precipitate (so-called self-weakening (7, 8).

Self-absorption of beta particles by Magnesium Pyrophosphate

A correction curve for self absorption was determined directly on magnesium pyrophosphate precipitates containing P^{32} in the following manner.

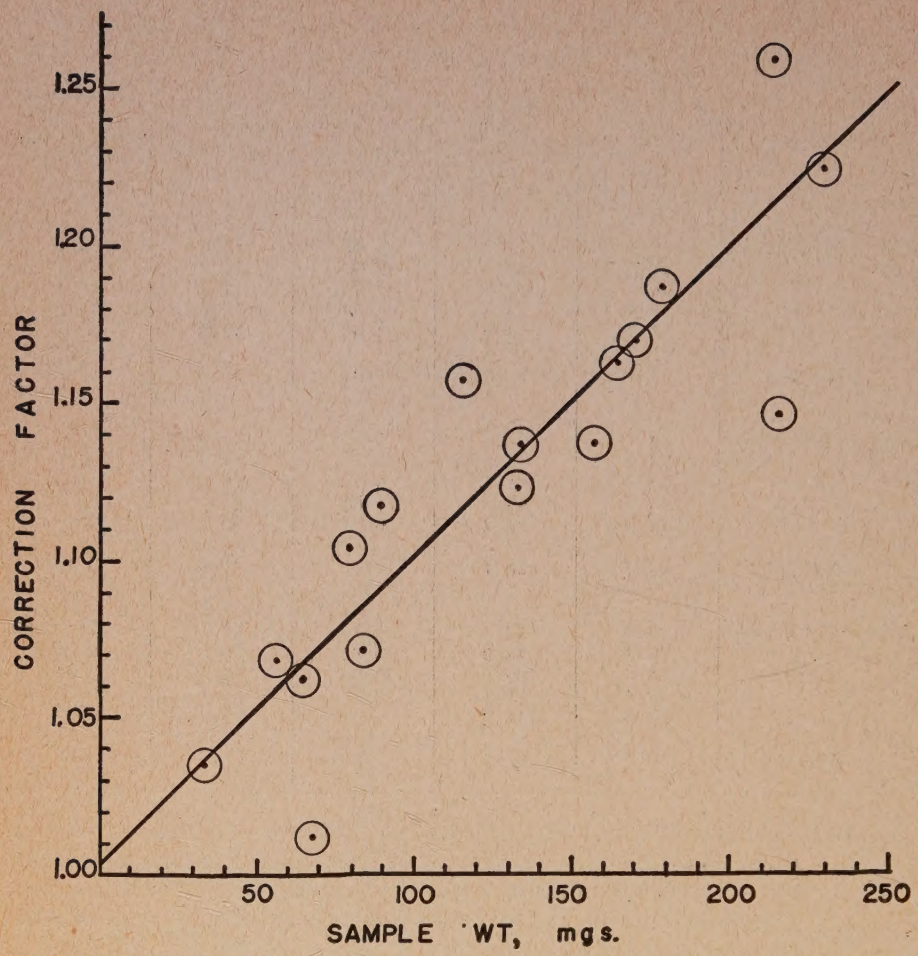

FIGURE 3. Correction curve for the absorption due to sample wt.

A phosphate solution containing 33.3 mg. of $Mg_2P_2O_7$ per ml. was made up. Various quantities of this solution were pipetted into centrifuge tubes. To each centrifuge tube 0.5 ml. of a solution of radioactive phosphorus was also added. The solution was mixed and precipitated as magnesium ammonium phosphate. The precipitates were transferred to weighed platinum dishes, 3.80 sq. cm. in area. The precipitate was carefully dried, ignited, counted and weighed. Several 0.5 ml. aliquots of the radioactive phosphorus solution, with no absorbing precipitate, were also evaporated and counted.

The results are shown in Table 1 and the graph of correction factor versus sample thickness is drawn in Figure 3. The standard deviation of the experimental points from the regression line is 0.023, giving an indication of the overall error introduced by pipetting, handling the precipitate, counting, geometry, etc.

RESULTS AND DISCUSSION

The results obtained from the plots harvested on the first three dates are tabulated in Table 2. Two plots were taken to maturity and before analysis they were split into four parts; seed, chaff (part of head remaining after removal of seed), stems and leaves. These results are shown in Table 3.

TABLE 3.—PHOSPHATE FERTILIZER UPTAKE AND DISTRIBUTION IN TWO PLOTS GROWN TO MATURITY (HARVEST DATE, AUGUST 11TH)

	Plot	Grain	Chaff	Stems	Leaves	Total
Weight, Grams	16	19.9	7.0	22.9	11.1	60.9
	17	28.5	9.5	32.6	15.3	85.9
Wt. of Total Phosphorus, mg.	16	60.4	11.1	9.4	10.3	91.2
	17	84.0	17.5	13.4	17.0	131.9
Wt. Fertilizer Phosphorus taken up, mg.	16	4.84	0.95	0.70	1.11	7.60
	17	4.81	0.68	0.72	0.75	6.96
Per cent fertilizer phosphorus taken up	16	14.6	2.9	2.1	3.3	22.9
	17	14.5	2.1	2.2	2.3	21.1
Per cent phosphorus in the plant coming from fertilizer	16	8.0	8.6	7.5	10.8	8.6
	17	5.7	3.9	5.4	4.4	5.3

TABLE 4.—AVERAGE VALUES FOR THE FOUR HARVEST DATES

Days from seeding	53	72	93	106
Stage of growth	Before shot blade	Heading	Early dough	Ripe
Weight of Plants, gm.	7.7	22.0	40.8	73.4
Height of Plants, inches	10	22	36	36
Wt. of Heads, gm.	0	2.7	13.2	32.5
Per cent phosphorus in the plant	0.30	0.25	0.20	0.15
Wt. of P in plant (mg.)	20.5	50.7	82.1	111.6
Per cent fertilizer taken up	12.9	21.3	23.7	22.3
Wt. P taken up from fertilizer (mg.)	4.3	7.1	7.9	7.3
Per cent phosphorus in plant which came from fertilizer	21.1	14.0	9.6	6.5
Per cent P in plant which came from the soil	78.9	86.0	90.4	93.5
Per cent P from the fertilizer that is in the head	0	24.0	62.1	77.5
Wt. of P from the fertilizer that is in the straw, (mg.)	4.3	5.4	3.0	1.6

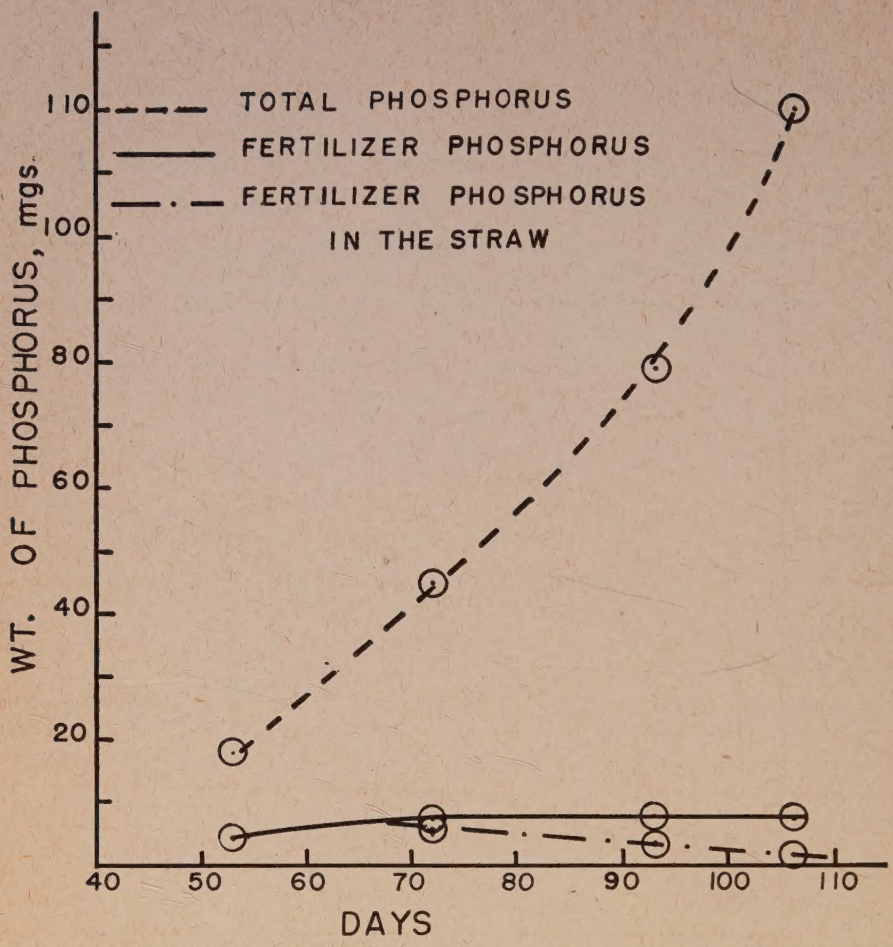

FIGURE 4. Graph showing the uptake of total and fertilizer phosphorus and the redistribution of the phosphorus in the plant.

The average values are summarized in Table 4 and are represented graphically in Figs. 4 and 5.

The foregoing results indicate that:

(a) there is an appreciable uptake of fertilizer phosphorus up until the heading stage.

(b) there is a large amount of phosphorus taken up by the plant in its later stages of growth but the amount of phosphorus coming from the fertilizer after heading is relatively small.

(c) there is a transfer of phosphorus from the leaves and stems of the plant to the head as the plant approaches maturity.

(d) within the limits of precision of the experiment, the phosphorus coming from the fertilizer appears to be uniformly mixed with the phosphorus coming from the soil in the different parts of the plant.

(e) under the conditions of our experiment, approximately 22% of the applied phosphorus was taken up by the plant.

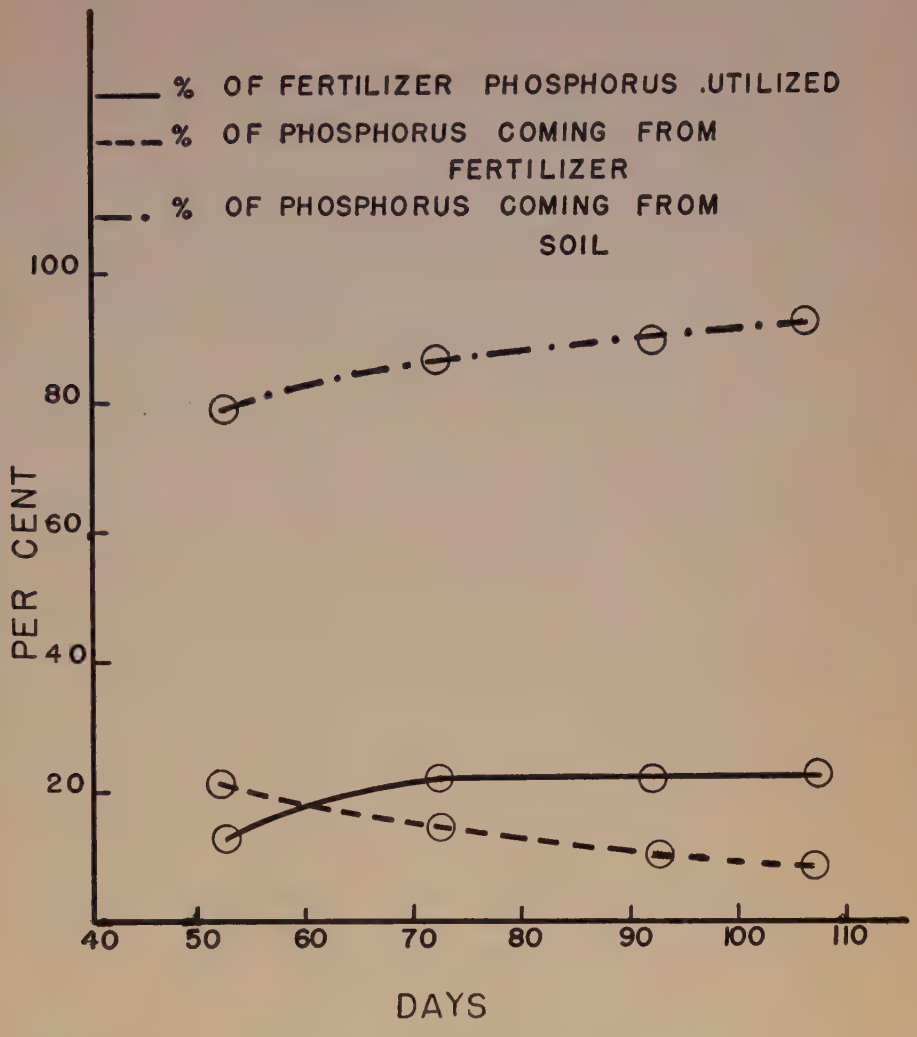

FIGURE 5. Graph of the percentage uptake of the fertilizer phosphorus and the relative amounts of soil and fertilizer phosphorus in the plant.

It is very important to note that the results obtained here are for this particular soil, this particular season and this particular method of applying the fertilizer. Results for other soils and other seasons might vary quite widely from these.

In this experiment the fertilizer was applied as a liquid. This would make it more liable to fixation at an early stage in the season and this might have some influence on the results obtained. The very small uptake of fertilizer in the later part of the season may be due in part to the spreading out of the root system away from the small area of soil in which the fertilizer was applied. However, it is probably also due to its fixation in the soil in a form not readily available to the plant (9).

The foregoing experiment indicates that the technique may be useful in studying directly a number of additional points:

(a) the uptake of fertilizer in the early stages of growth;
(b) the degree to which fertilizer not utilized by one crop can be used by a subsequent crop;
(c) differentiation of the phosphorus into inorganic, organic, etc.
(d) soil fixation experiments;
(e) the effect of soil, weather and mode of application on fertilizer utilization.

Experiments on most of these points have already been started.

SUMMARY

Radioactive phosphorus (P^{32}) has been used to measure the uptake of fertilizer phosphorus in wheat plants at different stages of growth. The main uptake of fertilizer phosphorus takes place prior to the heading out stage. The uptake of fertilizer phosphorus during the later stages of growth is relatively small although the total uptake of phosphorus after heading is quite large.

Under the conditions of our experiment approximately 22 per cent of the fertilizer phosphorus was recovered by the plant.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the National Research Council of Canada for financial support, to Mr. Agar for the use of part of a field, and to Dr. J. Mitchell, Head of Soils Department, for helpful advice and encouragement.

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THE FIELD INCREASE OF CEREALS DURING THE WINTER MONTHS[1]

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The time required to produce new varieties restricts the usefulness of plant breeding to agriculture. Furthermore, as Aamodt (1) has emphasized, no new variety can be expected to be permanent; in fact, its period of service may be very short because of changing conditions and new hazards of production. It is true that production problems which develop can be solved by breeding programs, but during the time the plant breeder is at work the grower may be suffering serious losses. Therefore, any improvement in technique which will lessen the time required to produce a new variety is of economic significance.

One method of shortening the time between the first cross and the producer is to grow a second field crop in another region during the winter months. Dr. C. H. Goulden, Officer-in-Charge, Dominion Laboratory of Cereal Breeding, Winnipeg, has informed the authors that he used such a scheme when developing stem rust resistant wheat varieties. He had an agreement with certain plant breeders in Australia, whereby each increased the other's material during the off-season. However, the long time required for transportation made it difficult to get the material back to Canada in time for spring seeding. Webber (5) describes a winter plant breeding station used by himself in a cotton improvement program. As this particular program required several backcross generations and the selfing of each, the use of the winter station resulted in a great saving of time. Several cereal breeders located in the Northern United States have informed the authors that they have grown winter crops successfully in Southern Arizona or California.

During the two winters (1944-1945 and 1945-1946) the Cereal Division of the Experimental Farms Service has grown winter crops of cereals in the Imperial Valley of California. This paper summarizes the observations made and the results obtained.

THE IMPERIAL VALLEY

The Imperial Valley is a depression, below sea level, in the Colorado Desert. It is located in the extreme southern part of California about 100 miles east of San Diego. El Centro is the principal city in the Valley.

The climate is characterized by relatively high temperatures throughout the year, with long hot summers, low humidity, a high rate of evaporation and a large number of days of intense sunshine. There is very little rainfall and the 2 or 3 inches usually received falls mostly in the winter months. The winter climate, according to Jacobs (3), is that of a low latitude desert and is characterized by relatively high day temperatures, low humidities and fairly frequent night time "radiation frosts". These

[1] Contribution No. 139 from the Cereal Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa, Canada. Presented in part at the annual meeting of the Western Canadian Society of Agronomy at Saskatoon, June, 1945.

[2] Assistant Cerealist, Cerealist, and Superintendent, respectively.

frosts do not occur with equal frequency or intensity in all parts of the district, due to elevation and to differences in exposure to wind. Some parts of the Valley are clearly "cold" and others clearly "warm". An examination of temperature records (4) shows that frosts occur even in the warmer areas, but they are seldom severe and occur generally in December or January before cereal crops have reached a critical stage of development. If a warm area is chosen as a plot site, there appears to be little danger of serious frost damage to fall sown cereals.

A comprehensive review of the agriculture of the Valley has been given by Cosby and Goar (2). It is highly diversified and many different crops are grown successfully throughout the year. Alfalfa is the basis of all rotations and occupies about 30% of the acreage. A large acreage of vegetables is grown during the winter months, including lettuce and carrots and smaller amounts of tomatoes, beets, cabbage and onions. Flax and barley are also important winter crops. Wheat does well, but only a very small acreage is seeded. Oats are not grown commercially. During the summer, melons and soiling crops are grown extensively. Other important crops grown in the Valley are rice, grapefruit and dates. As the rainfall is exceedingly scanty, all crops are irrigated throughout their growth period with water from the Colorado River.

OUTLINE OF PROGRAM

The first experience of the Cereal Division with winter increase was gained during the winter of 1943-1944, when Mr. L. G. Goar, Officer-in-Charge of the Imperial Valley Field Station, at Meloland, kindly arranged to grow 10 pounds of a promising wheat hybrid. This was seeded on one-half acre of land and produced 14 bushels. These excellent results seemed to warrant a more extensive program.

Accordingly 5 acres of land were rented for the 1944-1945 season. This land was leased from Mr. K. Mets and was located 7 miles south of Holtville. The plots were in an open field on silty clay loam soil. In the 1945-1946 season, the plots were in the same general location, but the soil was much lighter and the area was protected on the north by a windbreak of high trees.

The material grown included wheat, oats, barley and flax and varied in stage of development from F_1 seed to 2-acre increase plots of new varieties. The seed samples were supplied by the Cereal Division, Central Experimental Farm, Ottawa; the Dominion Laboratory of Cereal Breeding, Winnipeg; and the Dominion Experimental Stations at Swift Current, Brandon and Scott. Because the seed came from many breeding programs, designed to produce new varieties for a wide range of Canadian conditions, it varied widely in genetic background and adaptability.

A supervisor, together with the necessary small plot equipment, was sent from Swift Current by truck. In 1944-1945 the supervisor, in this case the senior author, stayed on the project during the entire season, but in 1945-1946 he returned to Swift Current after seeding. Machines for preparing the land and harvesting the larger plots were rented locally.

Seeding was done during the period from October 20 to November 3 in each year.

CROP REACTIONS

The 1944-1945 crop was quite successful. Average yields of approximately 40 bushels of wheat, 60 of barley, 30 of flax and 100 of oats per acre were obtained. The yields of wheat, barley and flax were lower than those usually obtained by growers in the Valley, and this is ascribed to the lack of adaptation of the Canadian material and to the withdrawal of irrigation water somewhat earlier than normal in order to hasten maturity. The majority of the flax and barley plots were harvested by April 15, and all were harvested by April 25. All wheat plots were harvested by May 1. The oats, however, did not mature until May 5. Their behaviour throughout the season was abnormal, as they did not head until March 28, but once heading commenced they grew rapidly and produced a good crop.

The 1945-1946 crop was not as good as that of the previous year. It was thought that by choosing a lighter soil and by having tree protection from cold winds maturity might be hastened. However, the light soil was not well adapted to cereal production, with the result that yields were somewhat lower, while the growth period was of equal duration. The trees were definitely harmful. All the plots seeded near them were partial failures. These included all the oats and a few plots of wheat. The oats produced a yield of only 40 bushels per acre. The other plots, away from the trees, produced satisfactory increases although, in general, yields were not quite as high as in 1944-1945.

The results to date show that flax is the most satisfactory crop for winter increase, because of its high yield and early maturity. Barley and wheat are satisfactory also, but oats are doubtful because of their late maturity. In addition, oats are subjected to the hazard of contamination with wild oats. This is a common weed in the fields and around ditch banks. It would be difficult to keep increase plots free from them.

Very large increases can be obtained by spaced seedings. F_1 barley plants, spaced a foot apart each way, produced up to 80 large spikes each. Similar results were noted with other crops.

The growing season for wheat in the Imperial Valley was approximately 175 days, whereas at Swift Current it is approximately 100 days. This difference is probably due to the slow growth in the Imperial Valley during December and January because of the low temperatures. During these months the plants remain more or less dormant. Such conditions are conducive to extensive tillering, which accounts for the enormous increases that can be obtained by space seeding. Heading takes place slowly, but from then on maturity is attained rapidly, because temperatures rise quickly as summer approaches. In general, the varieties mature in the same relative order as in Canada. However, occasionally a plot will head and mature much earlier than the general average. This difference may be as much as a month. Growth in such plots is usually poor, and the yield less than average.

Segregation for many characters was easy to detect. Differences in time of heading were great. Wheat lines that headed only a couple of days apart at Swift Current varied by as much as two weeks in California. The development of awns and the pigmentation of glumes and straw was very pronounced.

Fertility was high. This was particularly noticeable in the F_1 of a cross between *Triticum durum* and *T. vulgare*. While counts were not made, there was no doubt that these plants set much more seed than plants from similar crosses grown at Swift Current. It was not determined whether the extra seeds were due to self-fertilization of normally sterile florets, or to natural crossing. If the former was the case, these seeds might be expected to give rise to plants having recombinations of characters not normally obtained. The abundance of pollen and the favourable weather conditions for fertilization might be used to advantage in a crossing or backcrossing program. These same conditions might result in more than usual natural crossing with consequent limitations to the growing of pure seed, but this point has not been checked.

No losses were caused by either diseases or insect pests during the two growing seasons. It is reported that stem rust attacks wheat frequently in the Valley, but as all the material being increased was resistant, no infection occurred in the plots.

COSTS

Land suitable for winter increase rents at about $75.00 per acre. This includes charges for irrigation water. Labour is available locally at from 60 cents to $1.00 an hour, depending upon experience. The rental costs of machinery for preparing land and for harvesting are about twice those usually charged in Western Canada. Living expenses are also about twice as great. One of the largest items is the cost of transporting the seed back to Canada. Because of the present congested traffic conditions, freight shipments cannot be relied upon to arrive promptly. Express shipments arrive in about 10 days at a cost of $11.00 per hundred pounds to points in Western Canada.

DISCUSSION

The experience gained has shown that the winter increase of wheat, barley, flax and, possibly, oats is practical. This can be used to advantage in most breeding programs to advance the populations a generation, to increase lines, selections and seed stocks, as well as to assist the plant breeder in other ways. Such would reduce the time needed to complete a breeding program by from 1 to 3 years, depending on the nature of the program and the greenhouse facilities at the disposal of the breeder. The economic benefit of this saving in time needs no elaboration. As a result of the program described in this article, three new varieties are, or will be, in the hands of the grower a year sooner than they would otherwise have been. These are Redman and Rescue wheats and Garry oats. It is conservatively estimated that these varieties will produce sufficient extra grain in one year to finance the program at the present scale for the next 4,000 years.

The winter increase of annual and biennial forage and horticultural crops seems worthy of investigation. If they could be grown successfully, a substantial saving in time would result, particularly in the case of biennial crops.

SUMMARY

Hybrid populations and increase plots of wheat, oats, barley and flax were grown as winter crops in the Imperial Valley of California during the winters of 1944-1945 and 1945-1946. Wheat, barley and flax plots all matured by May 1 and gave high yields. Oats were a few days later in maturing and gave high yields in 1944-1945 but low yields in 1945-1946. By means of winter increase, the cereal breeding program can be materially shortened with resultant economic advantage to the country as a whole.

ACKNOWLEDGMENTS

Mr. Gordon Ross, Moose Jaw, supplied much useful information on conditions in various parts of California when the project was first being planned. Mr. L. G. Goar, Officer-in-Charge, Imperial Valley Field Station, Meloland, and Mr. Keith Mets, Holtville, gave freely of their time and long experience in advising on methods of seeding, irrigating, and other cultural practices. Without this help the project could not have been carried out. Mr. D. S. McBean, Assistant Cerealist, Dominion Experimental Station, Swift Current, harvested the 1945-1946 crop, and made many of the observations recorded in this paper.

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APPLES AS A SOURCE OF VITAMIN C[1]

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As early as 1912 interest was manifested in the Vitamin C content, or, as it was then known, the antiscorbutic factor, of apples. In that year Holst and Frolich (4) fed guinea pigs 30 gms. of raw apple daily to supply the antiscorbutic factor in the diet. Of four animals fed on the same diet three died on the 39th, 51st and 52nd days. The last two showed scurvy symptoms at post-mortem examination. The fourth animal was still alive after 87 days. The workers concluded that apples were not a good source of the antiscorbutic factor.

Bracewell, Hoyle and Zilva (1) tested a number of English apple varieties for the antiscorbutic factor and found Bramleys Seedling to be the best, being considerably above the others. In their test of a number of varieties of imported apples they found that antiscorbutic activity was greatest soon after harvesting.

In the study by Fellers, Isham and Smith (3) on the Vitamin C distribution in Baldwin and McIntosh apples the skin contained four times as much as the contiguous flesh and six to ten times as much as the flesh surrounding the core. McIntosh was low while Baldwin was a good source of Vitamin C.

Smith and Fellers (7) tested twenty-one varieties of apples grown in Massachusetts. Using guinea pigs as test animals they rated the varieties as follows:

Very Good—Baldwin, Northern Spy, Ben Davis, Winesap.

Good —Esopus, Rome Beauty, Red Astrachan, King Roxbury Russet, Rhode Island Stayman.

Fair —Arkansas, Gravenstein, Wealthy, Cortland, King David, Golden Delicious.

Poor —Jonathan, Delicious, Tolman, McIntosh.

The daily protective level for guinea pigs varied from 4 gms. for Baldwin to over 25 gms. for McIntosh.

Johansson (5) in Sweden found that Blenheim, Ecklinville and Wellington contained 20-25 gms. of Vitamin C per 100 gms. while Bramley, Golden Noble, Ontario and Transparente de Croncels had about 30 mgms. White Winter Calville was found to be much higher than all other varieties, the mean of three years' crops being 50 mgms.

The New York State Agricultural Experiment Station (6) have also reported on Calville Blanc. They found that for two years this variety averaged 37 mgms. per 100 gms.

In 1940 the writer did Vitamin C determinations on Canadian grown apples. The data obtained were not published at the time due to wartime difficulties. The indophenol titration method was used and peel and cortex were analysed separately. The following results were obtained:

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TABLE 1

Variety	Average diameter	Peel	Cortex	Vitamin C per cored apple
	Inches	Mgms. Vit. C per 100 gms.	Mgms. Vit. C per 100 gms.	Mgms.
Wagener	2.25	44	12	19.9
Sandow	3	20.6	11.2	19.5
Donald	3	28.4	5.2	14.8
Wealthy	2.75	23	5.7	12.2
Northern Spy	2.5	20	7.0	12.0
Russet	2.75	16.3	6.9	11.1
Atlas	2.5	22.0	3.3	9.4
Rome Beauty	3	31.0	2.6	9.4
Linda	2.75	6.4	5.5	9.0
Cortland	3	14.7	3.7	8.5
Duchess	2.5	8.6	3.8	7.0
Baldwin	2.25	25.0	2.0	6.1
Gravenstein	2.75	6.4	2.8	4.9
Nonpareil	2.5	16.2	0.9	4.6
Joyce	3	4.8	1.9	4.5
Lobo	2.75	9.0	1.6	4.0
Cox Orange	2.5	4.6	2.8	3.7
Gano	2.75	12.6	0.9	3.4
Blenheim	3	6.4	0.9	2.9
Melba	2.5	2.9	1.9	2.7
Stark	2.75	7.7	0.9	2.6
Ribston	2.5	6.4	0.9	2.2
McIntosh	2.5	5.2	0.9	1.6
King	3	3.6	Trace	1.1

The Division of Chemistry, Science Service, Dominion Department of Agriculture (2) analysed 338 varieties and seedlings and of this number have found 19 to contain more than 15 mgms. of Vitamin C per 100 gms. of peeled and cored fruit. The following were high in this group:

Variety	Mgms. Vit. C per 100 gms.
Tony Crab	32
Red Tip Crab	27
Wapella	25
Gertrude	24
Transparent × Wealthy	21

From the above tables and the literature cited it can be seen that there is a wide variation in the Vitamin C content of different apple varieties. There are also many references in the literature, not quoted here, that bear out the same fact.

While some popular dessert varieties are quite low in Vitamin C content it is evident from the above figures that certain varieties of apples are a very good source of this vitamin. Thus, Wagener, Northern Spy and Russet which are popular dessert varieties are quite high in Vitamin C. As a comparison: oranges supply 35 to 55 mgms. of Vitamin C, per 100 gms., grapefruit 35 to 40 mgms. and tomatoes 15 to 30 mgms. per 100 gms. of fruit. Thus some of the varieties reported above compare very favourably with citrus fruits as a source of Vitamin C. In eating a "220" orange, a popular dessert size, one obtains about 55 gms. of Vitamin C; slightly more than this, or about 60 mgms. are obtained from eating three $2\frac{1}{4}$ inch Wagener apples.

The data given in Table 1 for Russet, Wagener and Northern Spy were obtained after these apples had been in storage about six months. These figures compare favourably with subsequent work done on fresh fruit of these varieties. This indicates that Vitamin C in apples is retained very well in storage. Johansson (5) also presents data to show that for the normal storage life of a variety there is good retention of Vitamin C.

Apples, besides their eye and taste appeal, are recognized as being very beneficial in human nutrition. They are a source of pectin, calcium, phosphorus and iron as well as Vitamins, A, B_1, G and C. With the stress that is at present being given vitamins it would be very desirable to have a good quality dessert apple that would be high in Vitamin C.

It is true that Calville Blanc and the varieties listed from the Division of Chemistry are not satisfactory eating apples. The New York State Agricultural Experiment Station in speaking of Calville Blanc say: "As an apple Calville Blanc can never be a popular kind even though high in Vitamin C. Few people will enjoy eating a fruit which is as unattractive in appearance and mediocre in quality as is Calville Blanc." This variety was at one time grown at the Experimental Farm at Ottawa but was long ago discarded as being an unsuitable variety.

By using varieties that are rich in Vitamin C even though poor in quality, plant breeders by breeding experiments and selection should be able to produce an apple that would be a very good source of Vitamin C and at the same time have the colour, flavour, etc., desired in a dessert apple.

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DIGESTIBILITY STUDIES WITH SWINE

III. DIGESTIBILITIES OF SOME ANIMAL BY-PRODUCTS, PEAS AND BARLEY[1]

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Continuing previous studies (1) and (2), the coefficients of digestibility were determined of the feeds listed in Table 1, using swine as experimental animals. The grains were medium ground. The chemical compositions of the feeds are given in Table 2[6].

Table 1.—Feeds used in digestibility trials

Kind of Feed	Source	Designation in Experiment
Tankage 50% Feeding	Canada Packers Company, Montreal	Tankage I
Tankage 50% Feeding	Swift Canadian Company, Toronto	Tankage II
Tankage 50% Feeding	City Renderers Limited, Montreal	Tankage III
White Fishmeal	Fasterfat, Limited, Halifax	Fishmeal I
Herring Meal	B.C. Packers Limited, Vancouver	Fishmeal II
Pilchard Meal	Nootka-Bonfield Co. Ltd., Vancouver	Fishmeal III
Peas, Arthur, graded No. 4 C.E. Marrow Fat	Central Experimental Farm, Ottawa	Peas
Barley, Velvet, graded No. 4 C.E. barley	Central Experimental Farm, Ottawa	Barley

Table 2.—Chemical composition of feeds
(Means of Eight Values)

Feed	Dry Matter, %	Chemical Composition of Dry Matter in per cent				
		Ash	Protein*	Ether Ext.	Crude Fibre	N-Free Ext.
Tankage I	92.88	30.71	52.74	10.07	1.70	4.78
Tankage II	94.80	35.62	43.01	14.89	1.90	4.59
Tankage III	92.87	29.88	54.18	10.76	1.85	3.33
Fishmeal I	89.21	19.04	78.83	2.08	Nil	Nil
Fishmeal II	92.10	12.02	74.26	6.37	Nil	7.36
Fishmeal III	91.79	13.74	73.15	2.84	Nil	10.27
Peas	88.29	3.47	25.07	1.20	5.52	64.75
Barley	87.30	2.83	13.84	2.03	6.41	74.90

* For Tankage, Fishmeal, Peas N × 6.25.
For Barley N × 5.83.

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[6] In the case of the tankages and of two of the fishmeals, values for carbohydrates are included. Three possible explanations may be given for such values in animal by-products. Firstly, it may be that in the course of manufacture, vegetable matter is incorporated into the feeds. Secondly, the protein factor may be incorrect. Finally, particularly in the case of the fishmeals, the products may contain some substances capable of producing carbohydrates on hydrolysis. When Fishmeal III was hydrolyzed with hydrochloric acid, two per cent of reducing substances was found by the ceric sulphate titration method.

In the digestion trials the eight feeds were fed in eight periods to eight purebred Yorkshire barrows in an 8 × 8 randomized Latin square. Each period consisted of 24 days. It was divided into a pre-experimental sub-period of four days, a change-over sub-period of six days, a preliminary sub-period of seven days and a collection sub-period of 7 days. Collections were made in metabolism cages, previously described (1).

Supplements of percomorph oil and salt were given. The animal products were fed with barley in the ratio of one part of the product to two of barley. Peas were fed with barley in the ratio of one to one. The coefficients of barley used to calculate the coefficients of other feeds were determined by feeding it as a sole ration. All rations were made up in a slop with water.

PROGRESS OF EXPERIMENTS

Occasionally, there were small feed refusals but not of sufficient magnitude to interfere with the carrying out of the trials. Two animals had to be discarded from the experiment. In Period 4, animal 4 receiving Fishmeal II, became sick and had to be replaced. In Period 7, animal 7 became semiparalyzed and had to be replaced. In both cases the results for that particular animal for that particular period were discarded.

RESULTS

In view of the extensive calculations, only summary tables are included in this paper. To determine whether or not the age and weight of the animal had any effect upon the results, the data in the 8 × 8 randomized Latin square remaining after the elimination of the above mentioned two results, were examined statistically using the missing plot technique of Yates (3). Since two animals were replaced, the effect of animal had to be ignored. The results were arranged by ration and by period. A summary of the mean coefficients for each period for dry matter and nitrogen is given in Table 3. These means include missing values but the statistical analysis takes this into consideration.

TABLE 3.—DIGESTIBILITY OF RATIONS AT DIFFERENT STAGES IN THE GROWING PERIOD (MEANS OF EIGHT VALUES)

Period No.	Coefficients of Digestibility in per cent	
	Dry Matter	Nitrogen
1	79.2	86.9
2	76.8	85.1
3	77.4	86.1
4	78.6	86.8
5	76.0	85.6
6	76.8	86.4
7	77.7	86.2
8	77.8	86.0
Nec. diff. at P=0.05	1.5	1.3

It will be noted that in the case of the dry matter, Periods 1 and 4 gave results slightly higher than the rest, but the other six periods gave identical results. As far as nitrogen was concerned, the value in Period 2 was slightly below the highest value, namely that in Period 1. Otherwise, there was no difference. It was concluded that the age and the weight of the pig had no influence upon digestibility. This substantiates previous results (1), (2).

The Coefficients of Digestibility of the rations are given in Table 6 in the Appendix and summarized in Table 4. The coefficients of digestibilities of the peas and animal by-products were calculated from the mixed rations with barley.

TABLE 4.—MEAN COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS

Feed	Coefficients of Digestibility in per cent						
	Dry Matter	Organic Matter	Nitrogen	Ether Extract	Crude Fibre	N-Free Extract	Total Carbohyd.*
Tankage I	51.7	71.0	81.2	104.5	21.0	—‡	— 73.9
Tankage II	44.1	64.9	79.3	98.5	15.2	—‡	—119.4
Tankage III	56.6	75.8	85.0	103.6	46.6	—‡	— 88.1
Fishmeal I	78.7	89.5	93.9	124.4	—†	—‡	—†
Fishmeal II	79.0	84.4	92.3	104.1	—†	—‡	— 9.0
Fishmeal III	75.3	82.8	91.4	115.3	—†	—‡	10.1
Peas	92.5	93.9	87.9	23.4	85.6	97.8	96.0
Barley	81.0	82.4	83.8	59.3	17.2	88.2	82.7

* Sum of crude fibre and nitrogen-free extract.
† None present in feed.
‡ Combined with crude fibre to give total carbohydrates.

Certain points are of particular interest. Firstly, there is the high digestibility of the carbohydrate fraction in peas. For instance, the coefficient of digestibility of the total carbohydrates was 96.0 per cent compared with 82.7 per cent for the barley. This is taken to indicate that the carbohydrates of the peas consisted of less complex polysaccharides and were more digestible than those of the barley.

Another noteworthy point is, the complete digestibility of the fat in the animal products and the low digestibility of the ether extract in the grain. The digestibility of the dry matter, organic matter and nitrogen of fishmeals was higher than that of the tankages. The low values for the digestibility of the dry matter of the tankages were due, in part, to the fact that approximately one-third of these feeds consisted of mineral matter.

The coefficients of the carbohydrates for animal products were meaningless but are included as a matter of record. The significance of the finding of a small amount of carbohydrate in this material, was discussed in the foot-note of the paper.

In Table 5 is given a summary of the values for digestible crude protein and total digestible nutrients in pounds per hundred pounds of dry matter. It will be seen from this Table that peas had the highest content in total digestible nutrients, followed by barley, the fishmeals, and lastly the tankages.

TABLE 5.—TOTAL DIGESTIBLE NUTRIENTS AND DIGESTIBLE PROTEIN IN DRY MATTER OF FEEDS (MEAN VALUES)

Feeds	Content in Pounds per 100 Pounds of Dry Matter	
	Digestible Crude Protein	Total Digestible Nutrients
Tankage I	42.8	65.5
Tankage II	34.1	67.6
Tankage III	46.1	70.3
Fishmeal I	74.0	78.7
Fishmeal II	68.5	82.8
Fishmeal III	66.9	73.3
Peas	22.0	90.7
Barley	11.6	81.4

The fishmeals had high contents of digestible protein, while the tankages had considerably smaller amounts. For a grain, peas contain a relatively large amount of digestible protein.

On the basis of the contents of T.D.N. and digestible protein, therefore, the fishmeals were superior to the tankages.

SUMMARY

1. Coefficients of digestibility were determined on eight feeds, using eight Yorkshire barrows. The feeds consisted of three tankages from different sources, three fishmeals from different sources, peas and barley. They were fed through nine periods.

2. The animals increased in weight from approximately 70 kilograms, to 160 kilograms. The age and weight of the pigs, however, had no effect upon the digestibility.

3. The digestibility of the non-protein fraction of the feeds was highest with peas, followed by barley and the fishmeals, with that of the tankages lowest.

4. The digestibility of the protein was highest with the fishmeals, closely followed by that of the peas. The digestibility of the barley protein was next, with that of the tankages lowest.

5. Ether extract in tankages and fishmeals was completely digested. With the grains, its digestibility was low.

6. The digestibility of the crude fibre was quite high with the peas and low with the barley. The fishmeals had no crude fibre and the tankages had less than two per cent, which was a negligible quantity.

7. The digestibility of nitrogen free extract with peas was close to 100 per cent; with barley it was something less than 90 per cent.

8. From the results on crude fibre and nitrogen free extract, it was concluded that the composition of the carbohydrate fraction of the peas was different from that of the barley, containing less of the more complex indigestible polysaccharides.

9. Total digestible nutrients were highest in the peas, followed by the barley, fishmeals, and, finally, by the tankages.

10. The digestible crude protein was high in the fishmeals, followed by the tankages, the peas and barley, in that order.

ACKNOWLEDGMENT

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APPENDIX

Table 6.—Coefficients of digestibility of individual feeds arranged by rations

Nutrient	Coefficients of Rations in per cent							
	Barley	Tank. 1	Tank. 2	Tank. 3	FM 1	FM 2	FM 3	Peas
Dry Matter	81.8	55.3	41.2	79.2	83.4	83.8	79.3	94.7
	80.2	47.1	33.1	54.8	78.6	81.5	73.2	96.6
	80.5	53.5	46.2	54.0	82.5	79.5	77.3	89.4
	81.2	57.5	37.6	65.1	81.9	81.4	79.2	94.3
	81.0	52.6	43.9	52.0	72.8	70.9	68.8	92.3
	81.3	44.7	52.8	56.3	78.9	75.4	75.8	91.2
	81.7	53.5	50.5	61.2	75.5	75.4	75.8	90.6
	80.7	54.7	45.5	52.5	75.8	83.7	73.1	91.2
		52.7	46.5	44.2				
		45.7	44.0	46.7				
Mean	81.0	51.7	44.1	56.6	78.7	79.0	75.3	92.5
Organic Matter	83.0	72.6	62.3	89.7	93.8	87.3	85.4	95.5
	81.6	65.8	50.9	72.9	88.2	87.2	79.7	97.6
	81.9	71.2	66.5	72.8	90.5	84.9	84.4	91.1
	82.5	78.1	59.6	88.8	90.6	87.5	85.3	95.5
	82.4	75.5	62.6	74.0	85.6	77.1	78.7	94.0
	82.6	65.9	73.3	77.0	91.0	81.0	83.0	92.7
	83.0	73.6	74.2	81.7	86.6	81.1	83.4	92.1
	82.0	74.9	70.0	73.0	89.7	88.7	82.1	93.0
		70.3	66.8	62.3				
		62.3	62.4	66.2				
Mean	82.4	71.0	64.9	75.8	89.5	84.4	82.8	93.9
Nitrogen	83.7	81.0	77.1	93.1	94.4	93.9	92.8	89.6
	80.7	76.6	73.7	85.3	95.1	92.8	91.1	87.9
	82.9	79.9	80.6	84.7	94.7	92.6	92.0	87.9
	85.4	83.6	78.1	85.9	94.0	93.2	92.4	88.8
	84.7	82.0	77.2	85.2	91.5	89.3	89.8	89.4
	85.3	81.8	83.6	86.6	95.6	92.5	92.6	86.8
	82.9	81.9	81.9	86.4	92.8	91.9	90.9	86.9
	84.6	81.2	80.0	84.8	93.0	91.9	89.7	85.9
		82.5	81.5	80.6				
		81.1	79.5	77.8				
Mean	83.8	81.2	79.3	85.0	93.9	92.3	91.4	87.9

TABLE 6.—COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS ARRANGED BY RATIONS —*Concluded*

Nutrient	Coefficients of Rations in per cent							
	Barley	Tank. 1	Tank. 2	Tank. 3	FM 1	FM 2	FM 3	Peas
Ether Extract	51.3	105.2	90.9	109.4	133.7	103.8	127.2	22.8
	55.6	101.9	91.3	102.7	104.3	99.2	108.1	33.0
	52.5	99.0	97.6	96.9	113.3	107.0	116.7	−18.0
	61.9	106.6	105.6	108.5	116.8	109.3	117.5	28.0
	60.3	112.5	89.5	109.8	128.8	93.3	118.5	38.5
	56.2	106.2	103.6	106.5	113.0	104.4	88.9	19.3
	67.3	102.7	104.8	108.7	127.2	100.9	111.7	35.7
	69.4	109.1	101.0	101.3	158.1	114.8	133.5	27.7
		102.1	100.2	94.6				
		99.4	100.2	97.8				
Mean	59.3	104.5	98.5	103.6	124.4	104.1	115.3	23.4
Crude Fibre	22.4	85.2	82.7	100.0				94.8
	21.3	45.3	46.3	81.8				118.7
	14.4	17.1	−31.6	25.5				61.7
	16.2	96.8	−35.0	235.7				97.7
	11.7	24.2	92.5	26.9				78.1
	21.1	19.0	− 6.5	53.1				78.0
	17.5	82.5	62.6	52.3				69.4
	12.9	− 2.3	11.7	−23.0				86.2
		−69.1	−27.5	−70.2				
		−89.1	−43.0	−16.3				
Mean	17.2	21.0	15.2	46.6				85.6
Nitrogen Free Extract	88.7							98.5
	88.0							100.8
	87.9							95.9
	88.1							99.4
	88.2							97.5
	88.0							96.9
	88.6							96.1
	87.7							97.1
Mean	88.2							97.8
Total Carbo-hydrates	83.5	− 54.6	− 95.5	14.8		−11.2	19.7	98.2
	82.4	− 77.8	−193.4	−147.5		18.0	− 6.8	102.3
	82.3	− 46.4	−131.7	−135.9		−40.5	19.2	93.5
	82.4	− 26.0	−178.3	69.0		23.4	20.2	99.3
	82.5	− 31.6	−136.2	−190.8		−28.9	−20.7	96.0
	82.5	−145.7	− 80.9	− 87.9		−21.1	22.8	95.2
	83.2	− 47.2	− 70.4	− 34.0		−33.5	11.8	94.2
	81.7	− 43.5	− 67.9	− 96.1		22.0	14.9	96.1
		−104.5	−103.6	−168.4				
		−161.8	−135.9	−104.2				
Mean	82.7	− 73.9	−119.4	− 88.1		− 9.0	10.1	96.0

THE EFFECT OF FLOODING ON EMERGENCE OF REED CANARY GRASS SEED[1]

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Reed canary, *Phalaris arundinaceae* L., is a valuable grass for hay and pasture and is particularly adapted to growing under moist and flooded conditions. According to Bolton and McKenzie (2), it will tolerate longer periods of spring flooding than several other cultivated grasses. Throughout Western Canada there are many low-lying areas, which are subject to prolonged periods of spring flooding. On these lands, providing the salt content of the soils is not excessive, Reed canary would be the most suitable grass to grow. A major problem is encountered in establishing this grass on such areas, since it is frequently impossible to seed until late June or July, due to the flooded condition prevailing in the early spring. Seedlings from such late dates of seeding would normally be subjected at any early stage to the driest weather of the year, and in many cases would not become established. Consequently it would appear most practical to seed low-lying lands in the fall, either early or just before freeze-up. When seeded early in the fall, germination would normally occur and the seedlings become well established by freeze-up. Seeds planted in the late fall would lie dormant during the winter. In the spring, seedlings and seeds from both dates of seeding would be subjected to periods of flooding ranging from several days to several months, depending on the location and amount of run-off water. It would seem desirable to obtain information on the effect of early spring flooding on both early fall and late fall seedings of Reed canary grass. The latter case was investigated recently and the results are reported in this paper.

LITERATURE

In Idaho, Christ (3) states that early fall seedings of Reed canary are more satisfactory than spring or early summer seedings on land subject to spring overflow. Fuelleman (5), dealing with the crop in Illinois, mentions that late spring or early summer seedings are seldom successful, and that where high water makes spring seeding unfeasible, late fall seeding should be practised. Arny (1) recommends October seeding in Minnesota on land where standing water is expected to interfere in the early spring. In Michigan, Harrison (6) suggests August 15th to September 1st seedings where the land is expected to be under water in the spring. Holden and Albert (7) state that in Wisconsin the grass may be seeded from early spring to mid-summer, or in late fall just before the ground freezes, but do not recommend seeding from August 15th to October 15th. No reference is made to time of seeding on spring flooded land. Scoth (8) advises seeding in the early fall on lands subject to overflow to enable the seedlings to become well enough established to resist washing-out or drowning. White and MacVicar (9) mention seeding just prior to freeze-up where there is no danger of seed being washed-out by water in the spring, but they do not deal with the possible effect of long periods of spring flooding on seeds sown at this time.

[1] Contribution from the Forage Plants Division, Dominion Experimental Farms Service, Ottawa, Canada.
[2] Assistants in Forage Crops.

The general impression from the literature reviewed is that either early or late fall seedings of Reed canary are preferable when seeding cannot be done early in the spring. However, no clear cut statements are made as to the outcome of fall seedings if they were subjected to long periods of spring flooding.

METHOD

Two experiments were conducted in the greenhouse to determine the effect of different depths of water and various lengths of flooding on the emergence of Reed canary grass seed.

In both experiments, Reed canary was seeded in gallon crocks. Dry, sieved. loam soil was put in the bottom of the crocks to a depth of one and one-half inches; the seeds were placed on top and then covered with half an inch of dry soil. One hundred seeds were planted in each crock from a sample which germinated 40 per cent, according to laboratory determinations.

The treatments in one experiment consisted of the application of six depths of water, ranging from one to six inches above the soil surface. These depths were maintained for 28 days. A check treatment was included in which the soil was kept moist to field capacity. The treatments were randomized and replicated four times.

The experiment on length of flooding consisted of ten treatments, including a check in which the soil was kept moist to field capacity. Immediately after seeding, all but the check crocks were filled with water to a depth of six inches above the soil surface, and maintained at this level until drained. Draining was done at seven day intervals for 63 days by siphoning with rubber tubing. The treatments in this experiment were randomized and replicated six times.

RESULTS

Depths of Flooding

Emergence in the check crocks began eight days after planting and was complete in 18 days. The experiment was terminated 28 days after planting, at which time no emergence had occurred in the flooded treatments, regardless of the depth of water maintained above the soil surface.

Length of Flooding

Emergence in the check was similar to the first experiment. With the flooded treatments no emergence occurred until the water was drained, but 12 to 15 days after draining emergence began for all flooding treatments and was complete about ten days later. The data in Table 1 show the per cent emergence of seedlings obtained in this experiment following the different periods of flooding. These data were analysed statistically following the usual transformation of data in per cent to degrees according to the formula $P = \mathrm{Sin}^2\theta$ (4). The transformed data are presented also in Table 1. The means for treatments are significant at the 5 per cent point and closely approach the 1 per cent point.

Table 1 shows that there was a decline in per cent emergence of seedlings from the check up to 63 days of flooding. It will be noted that the emergence from the 21, 35 and 49 day periods of flooding is lower than that of the previous as well as the following periods. This may have been caused by the lower greenhouse temperature which prevailed at the time seedlings were emerging from these treatments.

TABLE 1.—EMERGENCE OF REED CANARY GRASS SEED FOLLOWING VARIOUS PERIODS OF FLOODING

Number of days flooded	Average per cent emergence	Average of data converted to $\text{Sin}^2\ \theta$
0 (check)	86.7	68.8
7	80.0	63.8
14	77.5	62.6
21	68.7	56.3
28	78.9	64.7
35	66.6	57.7
42	72.9	59.3
49	55.4	48.0
56	66.6	55.0
63	62.5	52.3

Minimum significant difference—11.34 (for converted data)

DISCUSSION

The results from these two experiments show that Reed canary grass seed, when planted in soil, will not emerge under flooded conditions. However, following drainage of the water, emergence begins in about 14 days. For periods up to 63 days of flooding, the total emergence is still fairly good and only a relatively small amount of seed viability is lost. This loss could be compensated for by increasing the rate of seeding accordingly. It would appear to be entirely feasible to seed Reed canary grass in the late fall on low-lying lands that would be flooded for long periods in the spring.

SUMMARY

In greenhouse experiments the effect of different depths of flooding and various periods of floodings on the emergence of seed of Reed canary grass, *Phalaris arundinacea* L., was determined. It was found that, when planted in soil, seed of this grass would not emerge under water but that emergence began about 14 days after draining. The number of seedlings which emerged following 63 days of flooding, while significantly lower than the emergence from soil kept at field moisture capacity, was still considerable. The results indicate that Reed canary grass seedings would be successful when made in the late fall just before freeze-up on land likely to be flooded for several weeks in the spring. The seeding rate could be increased to compensate for the loss of seed viability from flooding.

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DIGESTIBILITY STUDIES WITH RUMINANTS

X. RELATIVE ASSOCIATIVE EFFECTS OF THE ROUGHAGES, TIMOTHY AND ALFALFA, WITH BARLEY[1]

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The original plan of this series of digestibility studies with ruminants comprised an investigation of the effects of four factors. These were, *(a)* Plane of Nutrition *(b)* Associative Effects *(c)* Species *(d)* Age. Our previous publications have dealt with one or both of the first two factors. In one such publication (5) data were presented on associative digestibility using roughages and succulents. It was concluded that there were no associative effects among hay, straw, silage and mangels, as far as total digestible nutrients were concerned.

Two other publications studied possible associative effects on digestibility when various grains were combined (3, 5). With mixtures of barley, oats and oil cake, or of wheat bran, gluten feed and soybean oil meal, associative effects were either absent or of small magnitude.

Possible associative effects between grains and hay were also investigated (4). The grains were barley, oats and oil cake. The hay was 90 per cent legume, of which one-fifth was alfalfa and the rest red clover and alsike. With oats, the values calculated from a mixed ration with hay were lower than when they were fed alone. With oil cake meal and barley, in general no associative effects resulted from mixing these with hay.

The further case of the associative digestibility between a grain and two different roughages is the subject of this paper.

Forbes and Swift (2) carried out digestion trials in which cornmeal was fed both with alfalfa hay and with timothy hay. The digestibilities of these rations, as well as of alfalfa alone and timothy alone, were determined. In each case, three animals were used. The digestibility of the cornmeal, as indicated by the digestible energy, digestible dry matter and digestible nitrogen-free extract, was lower when it was calculated from the timothy ration than when it was calculated from the alfalfa ration. It should be noted that there was considerable variation in the calculated values. For instance, the ranges in the digestibility of the dry matter and nitrogen-free extract of the corn calculated from the ration with timothy, were respectively 12.7 absolute per cent and 16 absolute per cent. Large variations in calculated values are also encountered in this laboratory. To compensate for this, it is our custom to carry out a large number of digestibility trials. It is believed that, in this way, a better estimate of the true mean value of any ration can be determined.

PROCEDURE

In the present experiment the digestibilities of five rations were determined. These were: barley alone, alfalfa alone, timothy alone, barley with timothy and barley with alfalfa. Both sheep and steers were used.

[1] Contribution No. 133, Division of Chemistry, Science Service, Dominion Department of Agriculture, Ottawa, Canada, in co-operation with Experimental Farms Service.
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[4] Dominion Agricultural Chemist.
[5] Dominion Animal Husbandman.

With the steers the timothy and alfalfa hays were fed at a level of 7 kilograms per animal per day. Barley was fed at 3 kilograms and the mixed rations at 5 of hay and 3 of barley. Rations for the sheep were based on the steer rations, using the ratio of the 0.73 power of the live weights. During the experiment these levels were not always maintained for reasons which will be described later.

The barley was "Velvet" grown in the season of 1945 at the Central Experimental Farm. The timothy was of fair quality; the botanical analysis is shown in Table 1. The alfalfa was second cut of good quality

TABLE 1.—BOTANICAL ANALYSIS OF TIMOTHY HAY

	%
Timothy	73
Legumes (alfalfa, red and alsike clovers)	16
Couch Grass	8
Sweepings and other weeds (night flowering catchfly)	3
	100

from the season of 1945, grown at the Central Experimental Farm. Since it was received in a cut condition it was not possible to make a botanical analysis. The barley was crushed; the alfalfa and timothy were cut in a corn-cutter. Supplements of iodized rock salt, feeding oil, wheat germ oil, calcium, phosphorus, copper, iron, cobalt and manganese were given.

For the digestion trials, five grade Shorthorn steers rising two years old and five Leicester-Shropshire sheep, 1 to 1½ years old, were used. The steers averaged 391 kilograms in weight and the sheep 33 kilograms. The weights remained approximately constant throughout the experiment. The steers were numbered 1 to 5 and the sheep 6 to 10. In the case of each species, the five rations were fed to the five animals in five periods in a 5 × 5 randomized Latin square. Periods were 28 days in length, consisting of a four day pre-experimental sub-period, a four day change over sub-period, an eight day preliminary sub-period and a twelve day collection sub-period.

PROGRESS OF EXPERIMENT

Of the 50 trials, the results of 3 were discarded because of feed refusals. In 10 others the collection period was shortened because of the occurrence of irregular feed consumption before the collection sub-period had ended. In each case, however, the full preliminary sub-period was completed and the consumption up to the time of removal from the trial was regular. In two of these cases the collection sub-period was four days, in seven it was six days, and in one it was eight days. The remaining 37 trials were completed as scheduled.

At the end of the planned experiment an extra period was carried out for both the sheep and the steers. In the statistical analyses to determine variations due to animal and period, only the results in the originally planned 5 × 5 square were considered. In comparing the different rations, however, the means of all the rations were used.

Calculations were made of the total digestible nutrients consumed per animal per day. These were compared with Brody's (1) maintenance standards. In the case of the steers the mean consumption was on the average for all the rations at the rate of 1.07 maintenance. In the case of the sheep the mean consumption of all the rations was 0.70 maintenance.

TABLE 2.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY (ANIMAL NUMBERS IN BRACKETS WITH DRY MATTER)

Nutrient	Period No.	Coefficients of digestibility in per cent of following rations						
		Timothy	Alfalfa	Timothy and Barley	Alfalfa and Barley	Barley	Barley calculated from ration with	
							Timothy	Alfalfa
		With Steers						
Dry Matter	1	50.7 (3)	59.2 (2)	62.5 (4)	69.3 (5)	80.1 (1)	78.6	84.5
	2	53.2 (2)	61.4 (3)	65.8 (5)	69.1 (1)	78.9 (4)	87.8	84.1
	3	52.7 (5)	59.7 (4)	61.0 (1)	66.0 (3)	76.6 (2)	74.8	75.4
	4	54.3 (1)	61.4 (5)	58.9 (2)	68.6 (4)	78.5 (3)	69.0	82.0
	5	53.5 (4)	59.5 (1)	63.8 (3)	66.5 (2)	—	82.6	76.9
	6	—	—	59.4 (3)	—	78.6 (1)	70.6	—
	6	—	—	65.7 (5)	—	81.0 (4)	87.5	—
	Means	52.9	60.2	62.4	67.9	79.0	78.7	80.6
	S.E.	±0.60	±0.48	±1.06	±0.68	±0.62	±2.89	±1.87
Organic Matter	1	51.7	60.0	63.7	70.7	82.1	79.6	86.0
	2	54.8	62.3	67.4	70.3	80.1	89.6	85.1
	3	54.2	59.9	62.7	67.4	78.6	77.1	77.1
	4	55.4	62.8	60.3	69.6	80.3	70.3	82.6
	5	54.4	60.4	65.5	67.8	—	84.7	78.2
	6	—	—	61.3	—	80.1	73.4	—
	6	—	—	67.5	—	82.0	89.8	—
	Means	54.1	61.1	64.1	69.2	80.5	80.6	81.8
	S.E.	±0.63	±0.61	±1.27	±0.66	±0.54	±2.90	±1.79
Nitrogen	1	46.3	65.1	65.2	72.9	71.5	79.5	79.5
	2	44.7	70.9	69.9	73.6	—	87.5	81.6
	3	46.1	70.0	60.8	69.3	65.1	70.9	69.5
	4	46.2	69.1	62.2	73.1	74.3	72.8	79.8
	5	56.4	70.7	66.2	72.8	—	83.2	80.1
	6	—	—	59.0	—	78.4	69.6	—
	6	—	—	66.9	—	78.5	85.3	—
	Means	47.9	69.2	64.3	72.3	73.6	78.4	78.1
	S.E.	±2.13	±1.06	±1.44	±0.77	±2.49	±2.76	±2.18
Ether Extract	1	37.9	17.7	60.6	52.3	64.6	90.9	89.9
	2	13.5	14.0	61.9	52.0	78.4	88.8	85.5
	3	9.0	9.7	52.1	48.8	50.5	68.3	80.7
	4	38.3	13.7	62.2	51.5	83.5	94.6	87.5
	5	41.5	13.9	58.4	50.4	—	89.8	84.0
	6	—	—	54.9	—	79.1	84.2	—
	6	—	—	50.0	—	85.6	74.2	—
	Mean	28.0	13.8	57.2	51.0	73.6	84.4	85.5
	S.E.	±6.92	±1.27	±1.85	±0.64	±5.51	±3.64	±1.56
Crude Fibre	1	37.9	49.4	38.7	48.7	35.4	−25.0	40.5
	2	47.7	52.0	47.0	47.0	9.3	59.3	24.4
	3	46.3	47.3	42.4	43.0	0.6	8.5	−11.8
	4	50.4	54.7	37.1	47.4	−3.9	−40.6	30.8
	5	46.4	45.0	45.5	37.2	—	43.8	−52.5
	6	—	—	42.5	—	1.2	14.9	—
	6	—	—	52.5	—	22.5	10.8	—
	Mean	45.7	49.7	43.7	44.7	10.8	10.2	6.3
	S.E.	±2.10	±1.71	±1.97	±2.09	±6.21	±13.26	±17.15

TABLE 2.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY (ANIMAL NUMBERS IN BRACKETS WITH DRY MATTER)—*Continued*

Nutrient	Period No.	Coefficients of digestibility in per cent of following rations						
		Timothy	Alfalfa	Timothy and Barley	Alfalfa and Barley	Barley	Barley calculated from ration with	
							Timothy	Alfalfa
		With Steers						
N-Free Extract	1	62.3	67.0	74.0	79.4	88.7	87.9	91.2
	2	63.1	68.3	76.6	79.9	87.5	93.1	92.0
	3	62.4	65.9	72.5	76.8	88.3	84.3	85.4
	4	61.0	67.3	70.7	78.2	88.8	80.4	88.2
	5	60.2	68.2	74.3	78.1	—	88.4	88.4
	6	—	—	70.1	—	88.3	79.5	—
	6	—	—	74.8	—	88.5	89.7	—
	Mean	61.8	67.3	73.3	78.5	88.4	86.2	89.0
	S.E.	±0.52	±0.14	±0.88	±0.54	±0.19	±1.89	±1.18
		With Sheep						
Dry Matter	1	50.7 (6)	58.8 (9)	59.7 (8)	66.0 (7)	82.8 (10)	77.8	76.5
	2	45.1 (7)	59.2 (8)	61.6 (10)	68.4 (6)	—	83.0	83.3
	3	51.3 (10)	60.2 (7)	56.2 (9)	65.6 (8)	79.3 (6)	68.4	75.4
	4	45.8 (8)	58.6 (10)	63.0 (6)	67.4 (9)	—	86.5	79.8
	5	51.9 (9)	61.0 (6)	61.2 (7)	70.2 (10)	82.4 (8)	82.1	87.9
	6	—	—	64.3 (9)	—	79.8 (6)	90.8	—
	6	—	—	—	—	84.2 (7)	—	—
	6	—	—	—	—	79.9 (10)	—	—
	Mean	49.0	59.6	61.0	67.5	81.4	81.4	80.6
	S.E.	±1.45	±0.45	±1.16	±0.84	±0.82	±3.16	±2.29
Organic Matter	1	51.5	59.3	61.5	67.8	84.4	80.4	80.1
	2	46.7	59.7	63.0	69.4	—	84.3	84.6
	3	52.4	60.4	58.1	66.8	81.0	71.4	77.5
	4	47.3	59.3	64.1	68.6	—	86.9	81.7
	5	52.7	61.2	62.8	71.2	83.4	84.1	88.7
	6	—	—	66.0	—	80.8	92.8	—
	6	—	—	—	—	85.7	—	—
	6	—	—	—	—	81.0	—	—
	Mean	50.1	60.0	62.6	68.8	82.7	83.3	82.5
	S.E.	±1.29	±0.37	±1.09	±0.75	±0.85	±2.91	±1.93
Nitrogen	1	37.8	65.0	61.8	67.7	79.4	80.4	64.3
	2	33.9	69.8	61.1	74.4	—	77.8	83.6
	3	41.8	71.4	45.5	67.9	75.0	51.2	64.4
	4	28.8	68.0	63.3	70.4	—	81.2	72.1
	5	53.2	73.3	65.9	74.4	72.4	91.0	84.5
	6	—	—	65.0	—	75.2	92.6	—
	6	—	—	—	—	81.8	—	—
	6	—	—	—	—	77.9	—	—
	Mean	39.1	69.5	60.4	71.0	77.0	79.0	73.8
	S.E.	±4.13	±1.43	±3.08	±1.48	±1.39	±6.08	±4.43
Ether Extract	1	38.9	12.0	53.3	43.6	81.9	75.0	72.9
	2	21.2	9.2	55.1	46.5	—	74.5	75.9
	3	16.7	10.3	60.9	45.6	82.8	81.6	76.6
	2	30.6	18.6	62.0	55.6	—	91.9	98.2
	5	43.1	10.1	54.3	56.2	86.4	79.0	97.0
	6	—	—	46.7	—	84.3	71.4	—
	6	—	—	—	—	72.2	—	—
	6	—	—	—	—	77.1	—	—
	Mean	30.1	12.0	55.4	49.5	80.8	78.9	84.1
	S.E.	±5.02	±1.70	±2.27	±2.66	±2.13	±1.89	±5.54

TABLE 2.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY (ANIMAL NUMBERS IN BRACKETS WITH DRY MATTER)—*Concluded*

Nutrient	Period No.	Coefficients of digestibility in per cent of following rations						
		Timothy	Alfalfa	Timothy and Barley	Alfalfa and Barley	Barley	Barley calculated from ration with	
							Timothy	Alfalfa
		With Sheep						
Crude Fibre	1	39.5	45.9	34.5	45.0	37.8	−33.3	26.7
	2	37.0	48.2	42.2	46.5	—	44.1	39.8
	3	47.3	48.4	34.3	43.0	30.5	−45.8	8.5
	4	43.0	47.9	45.2	47.2	—	73.6	46.6
	5	43.4	46.1	42.6	47.7	40.0	48.1	51.0
	6	—	—	47.8	—	28.0	100.0	—
	6	—	—	—	—	46.6	—	—
	6	—	—	—	—	20.9	—	—
	Mean	42.0	47.3	41.1	45.9	34.0	31.1	34.5
	S.E.	±1.78	±0.54	±2.27	±0.85	±3.78	±23.86	±7.69
N-Free Extract	1	61.5	68.1	73.3	77.5	90.0	90.7	87.9
	2	56.3	65.8	73.1	78.9	—	89.9	90.5
	3	58.9	66.2	70.5	76.5	86.9	84.0	85.5
	4	53.9	65.5	73.2	77.3	—	89.6	87.0
	5	59.7	67.9	71.7	79.7	89.0	86.9	92.1
	6	—	—	74.6	—	87.3	93.1	—
	6	—	—	—	—	90.6	—	—
	6	—	—	—	—	87.5	—	—
	Mean	58.1	66.7	72.7	78.0	88.6	89.0	88.6
	S.E.	±1.34	±0.54	±0.61	±0.58	±0.63	±1.29	±1.19

RESULTS

In Table 2 are given the individual coefficients of all the rations as well as the values for barley calculated from the two hays. In Table 3 are given the total digestible nutrients of barley. In both Tables standard errors of the means have been included. In certain cases large variations will be noted.

TABLE 3.—TOTAL DIGESTIBLE NUTRIENTS IN PER CENT OF DRY MATTER (ANIMAL NUMBERS SHOWN IN BRACKETS)

Species	Period No.	Total Digestible Nutrients in following rations						
		Timothy	Alfalfa	Timothy and Barley	Alfalfa and Barley	Barley	Barley calculated from ration with	
							Timothy	Alfalfa
Steer	1	49.3 (3)	55.4 (2)	62.0 (4)	67.4 (5)	81.6 (1)	79.3	86.1
	2	52.3 (2)	57.6 (3)	65.9 (5)	67.3 (1)	—	90.3	86.1
	3	51.6 (5)	54.7 (4)	61.0 (1)	63.9 (3)	77.8 (2)	77.0	76.9
	4	52.9 (1)	57.7 (5)	59.1 (2)	66.7 (4)	80.6 (3)	72.0	83.7
	5	51.9 (4)	55.2 (1)	63.8 (3)	64.5 (2)	—	85.3	77.7
	6	—	—	59.9 (3)	—	80.8 (1)	74.2	—
	6	—	—	65.9 (5)	—	82.8 (4)	90.4	—
	Mean	51.6	56.1	62.5	66.0	80.7	81.2	82.1
	S.E.	±0.61	±0.64	±1.04	±0.73	±0.83	±2.48	±2.01

TABLE 3.—TOTAL DIGESTIBLE NUTRIENTS IN PER CENT OF DRY MATTER (ANIMAL NUMBERS SHOWN IN BRACKETS)—*Concluded*

Species	Period No.	Total Digestible Nutrients in following rations						
		Timothy	Alfalfa	Timothy and Barley	Alfalfa and Barley	Barley	Barley calculated from ration with	
							Timothy	Alfalfa
Sheep	1	48.9 (6)	54.6 (9)	60.0 (8)	64.5 (7)	84.6 (10)	80.3	79.9
	2	44.3 (7)	55.0 (8)	61.6 (10)	66.5 (6)	—	84.9	85.8
	3	50.2 (10)	55.4 (7)	56.3 (9)	63.5 (8)	81.6 (6)	70.9	77.4
	4	45.3 (8)	54.8 (10)	62.8 (6)	65.8 (9)	—	88.1	83.1
	5	50.4 (9)	56.1 (6)	61.4 (7)	68.0 (10)	83.7 (8)	85.1	89.1
	6	—	—	64.0 (9)	—	80.9 (6)	92.5	—
	6	—	—	—	—	85.3 (7)	—	—
	6	—	—	—	—	80.7 (10)	—	—
	Mean	47.8	55.2	61.0	65.7	82.8	83.6	83.1
	S.E.	±1.27	±0.27	±1.09	±0.78	±0.81	±3.03	±2.07

TABLE 4.—MEAN COEFFICIENTS OF DIGESTIBILITY OF DRY MATTER AND NITROGEN, ARRANGED BY ANIMAL AND PERIOD

Species of Animal	Mean values for Animal			Mean value for Period		
	Animal No.	Coefficients of Digestibility		Period No.	Coefficients of Digestibility	
		Dry Matter	Nitrogen		Dry Matter	Nitrogen
		%	%		%	%
Steer	1	64.8	64.6	1	64.4	64.2
	2	62.9	62.0	2	65.7	66.4
	3	64.1	65.4	3	63.2	62.3
	4	64.6	67.8	4	64.3	65.0
	5	66.0	66.1	5	64.8	68.1
Sheep	6	64.5	64.8	1	63.6	62.3
	7	62.5	62.8	2	63.0	62.8
	8	62.5	60.1	3	62.5	60.3
	9	63.0	61.6	4	63.1	60.6
	10	64.9	64.9	5	65.3	67.8

In Table 4 the mean coefficients for each animal and for each period of dry matter and nitrogen are given. The significances of the variations were calculated. In the case of the dry matter with steers, there was one missing value and the technique of Yates (7) for a randomized Latin square with one missing value, was used. In the case of the remaining values, there were two missing values in the 5 × 5 square. Therefore, the technique used was that of Yates for columns and rows, with two missing values. In all cases the variations between the animals and between periods were not statistically significant. In the case of the sheep, however, the nitrogen results in Period 5 were somewhat higher than those of the other four periods. Over all, it was concluded that neither the individualities of the animals nor the different periods affected the results.

TABLE 5.—MEAN COEFFICIENTS OF DIGESTIBILITY AND T. D. N. IN DRY MATTER OF BARLEY WHEN FED ALONE AND WHEN CALCULATED FROM MIXED RATION WITH TIMOTHY AND ALFALFA

Species	Nutrient	Mean coefficients of digestibility of barley when			Differences between barley for following comparisons		
		Fed Alone	Calculated from Timothy	Calculated from Alfalfa	Timothy and Alfalfa	Alone with Timothy	Alone with Alfalfa
Steer	Dry Matter	79.0	78.7	80.6	−1.9	+ 0.3	− 1.6
	Org. Matter	80.5	80.6	81.8	−1.2	− 0.1	− 1.3
	Nitrogen	73.6	78.4	78.1	+0.3	− 4.8	− 4.5
	Eth-Extract	73.6	84.4	85.5	−1.1	−10.8	−11.9
	Crude Fibre	10.8	10.2	6.3	+3.9	+ 0.6	+ 4.5
	N-free Extract	88.4	86.2	89.0	−2.8	+ 2.2	− 0.6
	T.D.N.	80.7	81.2	82.1	−0.9	− 0.5	− 1.4
Sheep	Dry Matter	81.4	81.4	80.6	+0.8	0	+ 0.8
	Org. Matter	82.7	83.3	82.5	+0.8	− 0.6	+ 0.2
	Nitrogen	77.0	79.0	73.8	+5.2	− 2.0	+ 3.2
	Eth-Extract	80.8	78.9	84.1	−5.2	+ 1.9	− 3.3
	Crude Fibre	34.0	31.1	34.5	−3.4	+ 2.9	− 0.5
	N-free Extract	88.6	89.0	88.6	+0.4	− 0.4	0
	T.D.N.	82.8	83.6	83.1	+0.5	− 0.8	− 0.3

In Table 5 are given three sets of mean coefficients of digestibility of barley. One was obtained by feeding it as a sole ration. The other two were obtained by calculation when it was fed with timothy and with alfalfa. The values of barley calculated from timothy were not statistically significantly different from those calculated from alfalfa. These results differ from those of Forbes, mentioned previously. In the first case, using cornmeal, the calculated coefficients fed with timothy were much less than those fed with alfalfa.

In the comparison of the values of barley fed alone with those calculated from the roughage rations, there was no difference of any magnitude except in one instance. That exception was the case of ether extract with steers. Such differences as existed were not statistically significant. This latter fact substantiates the conclusions of the previous investigation on associative effects between roughages and grains (4).

SUMMARY

1. Using 5 grade Shorthorn steers and 5 Shropshire-Leicester cross sheep, the coefficients of digestibility of barley, timothy hay, alfalfa hay, and of mixed rations of barley with timothy and barley with alfalfa, were determined.

2. The digestibility of barley when it constituted the sole ration was compared with the digestibility when calculated from a ration of barley with timothy and from a ration of barley with alfalfa.

3. It was concluded that the digestibility of barley was the same when fed with timothy, when fed with alfalfa or when fed alone to sheep or steers.

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APPENDIX

Table 6.—Chemical composition of feedstuffs

(Mean of five values)

Feed	Dry Matter %	Chemical Composition of Dry Matter in per cent				
		Ash	Protein*	Ether Extract	Crude Fibre	N-Free Extract
Alfalfa Hay	84.60	8.11	16.69	1.19	31.76	42.25
Timothy Hay	86.86	5.23	7.16	1.10	37.79	48.72
Barley	85.64	3.14	13.90	2.12	6.74	74.11

*N-factors—Alfalfa and timothy, 6.25
—Barley, 5.83

A NOTE ON THE REACTION OF CERTAIN BARLEY VARIETIES TO RACE 15B OF STEM RUST (*PUCCINIA GRAMINIS TRITICI* ERIKSS. AND HENN.)[1]

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INTRODUCTION

The possibility of the occurrence of new races of stem rust and the existence of biotypes within races has been recognized for some time. Recently biotype B of race 15 has been isolated a number of times in collections of stem rust made in the United States (1, 3, 6) but as yet has not been isolated in Canada. According to Hart (1) race 15B is a virulent type to which the commercial varieties of wheat, considered resistant to stem rust, are susceptible. These include such varieties as Regent, Renown, Thatcher, Apex, Mindum, Carleton and others which are being grown in Western Canada. The possibility of the occurrence and increase of race 15B in Canada cannot be ignored.

Since barley is also attacked by *Puccinia graminis Tritici* it was thought that it would be eminently worth while to test the reaction to race 15B of certain barley varieties and promising hybrids.

MATERIAL AND METHODS

During the 1946 growing season, through the courtesy of the officers of the Dominion Laboratory of Cereal Breeding, and Dominion Laboratory of Plant Pathology, Winnipeg, 28 named barley varieties and 41 hybrids were sown in their rust nurseries.

One nursery was inoculated only with race 15B on susceptible border rows. This nursery was a distance of approximately 200 yards from the closest plots artificially inoculated with races other than 15B. The effectiveness of the inoculum in this nursery was proven by the fact that wheat varieties such as Regent, Renown and Thatcher were severely infected with stem rust. These varieties are normally resistant to all other common races.

The same set of barley varieties and hybrids was sown in the regular rust nursery which was inoculated with a mixture of approximately 50 races of stem rust other than 15B. In this nursery, Regent, Renown and Thatcher maintained their usual high resistance.

In each nursery the varieties and hybrids were sown systematically in five foot rows in duplicate blocks. Rust readings were taken on a percentage basis at maturity.

RESULTS

Heavy infections of rust were obtained on susceptible varieties in both rust nurseries. The maximum infections were 70% and 80% for the 15B nursery and the regular nursery respectively. The agreement of rust

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TABLE 1.—COMPARISON OF THE REACTION OF BARLEY VARIETIES TO RACE 15B AND OTHER RACES OF STEM RUST

Variety	C.A. No.	C.I. No.	Race 15B % Rust	Other Races % Rust
Can. Thorpe	816		70.0	70.0
Chevron	1121	1111	t	t
Colsess	774	2792	35.0	35.0
Compana	1154	5438	32.5	35.0
Galore	1126	7150	45.0	35.0
Gartons	1134	7016	t *	t **
Glacier	1149	6976	37.5	40.0
Hannchen	837	531	50.0	60.0
Icelandic	90		25.0	25.0
Kindred	1155	6969	t	t
Mars	1157	7015	t−t+	t
Mensury (Ott. 60)	730	4696	40.0	40.0
Montcalm	1135	7149	52.5	45.0
Newal	1089	6088	40.0	30.0
O.A.C. 21	1086	1470	50.0	40.0
Olli	739	6251	30.0	25.0
Peatland	772	5267	t	t
Plush	1106	6093	37.5	27.5
Prospect	1140	6339	45.0	30.0
Regal	742	5030	55.0	55.0
Rex	1113	6618	65.0	60.0
Sanalta	1088	6087	57.5	60.0
Titan	1118	7055	30.0	40.0
Trebi	753	936	35.0	20.0
Tregal	1150	6359	30.0	25.0
Velvet	1133	4252	57.5	75.0
Velvon	1151	6109	50.0	30.0
Wisc. Ped. 38	1101	5105	40.0	40.0

* Four rusted plants were found in this plot.
** Two rusted plants were found in this plot.

readings between replicated plots within each test was good. In each test there were only two cases in which varietal readings differed by more than ten per cent.

Table 1 presents the average stem rust infection in both rust nurseries for the 28 varieties tested. The outstanding observation to be derived from this table is that the reaction of all varieties to race 15B as compared to the other races was essentially identical. The normally resistant varieties were resistant in both cases and the normally susceptible varieties were susceptible in both cases. There was some variation in percentage of rust on some susceptible varieties between the two rust nurseries, but in all cases where more than a trace of rust was found the pustules were large and open.

Results on the hybrids will not be reported in detail here, as they are only of limited interest. However, of the 41 hybrids tested, 35 have Peatland in their parentage and had been selected for resistance to races of stem rust other than 15B. These 35 hybrids gave essentially the same reaction to race 15B as they did to the other races. Thirty-one showed only a trace of rust in both nurseries and four were mixed in reaction in both nurseries. The other six hybrids were susceptible in both nurseries.

DISCUSSION

The above results indicate that adult plant reaction to race 15B is governed by the same gene or genes which control adult plant reaction to the other races of stem rust. In both Peatland (4) and Chevron (5, 2) adult plant reaction is governed by the same single gene.[1] In the case of Peatland, the above statement is borne out by the fact that the 31 hybrids derived from Peatland are resistant to race 15B after having been selected only for resistance to races other than 15B. If another gene for reaction to race 15B were present in Peatland it is highly improbable that its allel for resistance would occur with the allel for resistance to the other races in all of the 31 hybrids mentioned above unless they were closely linked.

In view of the above results, barley breeding programs in which resistance to stem rust is one of the objectives need not be interrupted in order to add resistance to race 15B if Peatland or Chevron (or possibly the other known resistant varieties) are being used as the source of resistance.

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[1] Unpublished data from R. G. Shands, Division of Cereal Crops and Diseases, Madison, Wisconsin.

TOXICITY OF SORGHUM IN SOUTHWESTERN SASKATCHEWAN[1]

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It is commonly accepted that sorghum (*Sorghum vulgare* Pers.) develops potential toxic substances in its tissues when injured by drought or frost. Sorghum has not been grown to any extent in Saskatchewan, and it is believed there have been no previous reports of stock fatalities.

In 1946, Black Amber sorghum was included in an annual fodder test conducted at four Experimental Substations, located at Kincaid, Bracken, Fox Valley and Tugaske, as well as at Swift Current.

Cattle were turned into the field at Kincaid after the test was harvested. Two mature cows and one suckling calf died with symptoms of hydrocyanic acid (HCN) poisoning. The suckling calf, two months old, died before its dam. A post mortem on the animals by a Government Veterinarian confirmed the supposition that HCN poisoning had been the cause of death. Mr. J. Ficht, Agronomist present at the Substation at the time, observed that leaves of the few remaining sorghum plants on the field had been eaten. He suspected that the sorghum plants were responsible for the poisoning. The matter was brought to the attention of the authors by Mr. P. J. Janzen, Substation Supervisor.

Plants were collected and analysed for HCN content. The analyses indicated that the plants contained a considerable amount of HCN. This finding led to further investigations on the toxicity of sorghum.

This paper presents the results of these investigations. Its main purpose is to bring to the attention of agrologists and farmers the danger of growing sorghum for feed in areas where drought and frost occur frequently.

LITERATURE

No attempt was made to review all the literature on sorghum poisoning. Only aspects pertaining to matters dealt with in this paper were reviewed.

Willaman and West (12) claim unhealthy plants contain more HCN than healthy ones. The unhealthy condition may be due to malnutrition, to improper transpiration, to insect attack, or to other causes. Since some varieties consistently contain more HCN than others, they believe varietal difference probably is more important in determining the amount of HCN produced than the conditions of growth. Pinckney (10) found the per cent HCN was low in light coloured, yellow to yellowish green plants, while in darker coloured plants it was high. The per cent HCN in dark coloured plants was several times as high in the leaves as in the stems.

Hopper *et al.* (7), Willaman and West (11), Menual and Dowell (9), Boyd *et al.* (2) and Pinckney (10) found that young sorghum plants and second growth material contained more HCN than older plants. Hopper

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et al. (7) claimed that, if normal growth were interrupted by adverse climatic conditions, the HCN content would increase. Franzke *et al.* (4) found 15 per cent less HCN in second growth sorghum than in first growth.

Willaman and West (12) and Franzke *et al.* (4), working with sorghum, were in agreement that adequate water supply was usually accompanied by low, and inadequate water supply by high HCN content. Franzke and Hume (5) found that sorghum plants, which were retarded in growth, maintained a higher level of HCN for a longer period than rapidly growing normal plants.

McKee and Sloan (8) claim there is some danger in pasturing sorghum which has been frosted or checked in growth by severe drought. However, once the crop has been cut and properly cured, there appears to be no danger from feeding the hay.

Franzke *et al.* (4) found second growth sorghum, tested 12 hours after it had been frozen, had lost 65 per cent of its original HCN. Franzke and Hume (6) in their investigations concluded that selected strains of sorghum differed with respect to liberation of HCN into the surrounding atmosphere during the process of growth. Two strains liberated no HCN during growth, but did so during the process of thawing after being frozen. Sorghum plants that had died and become air dry no longer liberated HCN.

In regard to lethal doses of HCN, Hopper *et al.* (7) and Durrell and Newsom (3) state that 5 pounds of plant material, containing as little as 0.02 per cent of potential HCN, would be lethal for a cow, and a little over one pound would be lethal for a sheep.

METHODS AND MATERIALS

All samples were analysed in duplicate for HCN content by the Alkaline Titration Method described in Methods of Analysis (1).

Samples of Black Amber sorghum were collected at Kincaid, Bracken, Fox Valley, Tugaske and Swift Current. Green material was analysed in most cases. However, a few samples were of cured material. Samples of green wheat, alfalfa and millet leaves were analysed and served as checks. Duplicate samples were used to determine the dry matter content of this material.

In order to obtain information on varietal differences in HCN content, fresh leaves of all varieties under test at Swift Current were analysed. Two of the varieties, Rancher and Early Amber, were grown in crocks in the greenhouse. Both varieties were subjected to artificial drought at three stages of growth. The plants were analysed when the entire plant showed definite signs of suffering from lack of moisture. In addition, each variety was subjected to frost at +15° F. for four minutes. This frost treatment was applied to first growth material in the heading stage, and to second growth material 8 inches high. About one-third of the leaves were damaged beyond recovery. The entire plants were analysed 24 hours after the frost treatment.

In all cases normal plants in the same stage of growth were analysed for comparison.

TABLE 1.—HCN CONTENT IN BLACK AMBER SORGHUM AND OTHER CROPS

Collected in Different Localities in Southwestern Saskatchewan

Source	Kind of Plant and Parts Analysed	Condition of Material when Analysed	Condition of Growth	On Dry Matter Basis HCN	Material as Analysed	
					HCN	Approximate Amt. to Kill a Cow**
				%	%	Lbs.
Substation						
Kincaid	Black Amber sorghum leaves	Green—fresh	Stunted—not headed	.175	.082	1.5
Kincaid	Black Amber sorghum leaves	Cured—hay	Stunted—not headed	.070	.061	1.7
Kincaid	Millet leaves	Green—fresh	Stunted—not headed	.010	.004	24.0
Bracken	Black Amber sorghum leaves	Green—fresh	Stunted—not headed	.089	.047	2.0
Tugaske	Black Amber sorghum leaves	Green—fresh	Normal—not headed	.047	.027	4.0
Fox Valley	Black Amber sorghum leaves	Green—fresh	Normal—not headed	.019	.006	15.5
Dom Exp. Station						
Swift Current	Black Amber sorghum leaves*	Green—fresh	Normal—heading	.133	.040	2.5
Swift Current	Black Amber sorghum leaves*	Cured—hay	Normal—heading	.011	.010	10.0
Swift Current	Black Amber sorghum stems*	Green—fresh	Normal—heading	.020	.004	24.0
Swift Current	Black Amber sorghum stems*	Cured—hay	Normal—heading	.010	.003	33.0
Swift Current	Alfalfa leaves	Green—fresh	6- 8 inches tall	.016	.004	24.0
Swift Current	Wheat leaves	Green—fresh	8–12 inches tall	.016	.004	24.0

* Samples were taken from a field of sorghum where some leaf tips of the plants had been slightly frosted.
** 5 pounds of plant material containing .02 per cent HCN is lethal to a cow (3, 7).

TABLE 2.—HCN CONTENT OF FRESH LEAVES OF SORGHUM VARIETIES

Grown at the Dominion Experimental Station, Swift Current, Sask.

Variety	Stage of Development	Approximate Height	P.C. of HCN on Green Wt. Basis	Approximate Amt. of Material Required to Kill a Cow*
		Ft.	%	Lbs.
Rancher	Heading	5	.008	12.5
Dakota Amber Low Acid	Heading	5	.010	10.0
Low Prussic Acid	Heading	5	.013	8.0
Black Amber	Heading	5	.019	5.0
Early Amber	Heading	5	.026	4.0
Honey Drip	No heads	4.5	.028	3.5
Waconia Orange	No heads	4.5	.031	3.0

* 5 pounds of plant material containing .02 per cent HCN is lethal to a cow (3, 7).

RESULTS

The HCN content of samples of Black Amber sorghum collected at the Substations and Swift Current is presented in Table 1. The material from Kincaid and Bracken contained exceptionally high amounts of HCN. At these two locations precipitation during the growing season was very light and the plants were severely injured by drought. At Tugaske and Swift Current, although plant development appeared normal, the leaves contained toxic amounts of HCN, whereas at Fox Valley where growth was similar the leaves were not toxic. Although the material from Kincaid decreased slightly in toxicity when cured, it remained very poisonous. On the other hand, curing the less poisonous material from Swift Current decreased the HCN content sufficiently to make it safe as feed for livestock. The stems contained much less HCN than the leaves. Stems analysed in the green state contained approximately the same amount of HCN as green leaves of wheat, alfalfa, and millet.

Data for the HCN content of the sorghum varieties under test at Swift Current are presented in Table 2. The toxicity of the varieties varied considerably. Rancher, Dakota Amber Low Acid and Low Prussic Acid contained one-third to one-half as much HCN as the other varieties.

The results of the greenhouse experiment with the sorghum varieties, Rancher and Early Amber, are summarized in Table 3. In the youngest stage, Early Amber contained considerably more HCN when injured by drought than Rancher. However, in the two subsequent stages there was little difference between the varieties. There was a definite decline in HCN content as the plants matured. In every case wilted material contained more HCN than the checks.

Neither of the varieties frosted in the heading stage showed any appreciable increase in HCN content over the checks, nor was there much difference between the varieties. Frosted second growth material of both varieties contained two to three times as much HCN as the checks. However, the difference between the varieties was small.

TABLE 3.—HCN CONTENT OF THE ENTIRE PLANT OF TWO SORGHUM VARIETIES GROWN IN THE GREENHOUSE

Subjected to Drought and Frost at Different Stages of Growth

Stage of Growth of the Varieties as Indicated by Plant Height in Inches		Early Amber P.C. of HCN		Rancher P.C. of HCN	
Wilted	Check	Wilted	Check	Wilted	Check
Ins.	Ins.	%	%	%	%
8	11	.026	.009	.017	.011
18	21	.016	.009	.018	.009
29	33	.006	.003	.008	.002
Frosted	Check	Frosted	Check	Frosted	Check
33*	33*	.003	.003	.003	.002
8**	8**	.024	.009	.025	.018

* First growth in the heading stage.
** Second growth.

DISCUSSION

Climatic conditions, such as severe drought and frost, tend to increase the formation of potential HCN in the tissues of sorghum plants. Since these conditions occur frequently in the Prairie Provinces and sorghum generally yields less than other annual fodder crops, the value of this crop, in the region, is doubtful. If sorghum is grown it is preferable to use low acid varieties, such as Rancher and Dakota Amber Low Acid.

Sorghum growth and climatic conditions at Fox Valley, Tugaske and Swift Current were similar, yet the HCN content of the material from Fox Valley was much less than that from the other two locations. This would indicate that there may be factors other than climatic conditions influencing the production of potential HCN in sorghum. Soil differences at these locations could be one of these factors.

SUMMARY

Analyses for HCN content were made on samples of: (1) Black Amber sorghum collected at four Substations and Swift Current; (2) Sorghum varieties under test at Swift Current, and (3) Rancher and Early Amber sorghum grown in the greenhouse and subjected to drought and frost.

Toxic amounts of HCN were found in practically all samples of Black Amber sorghum collected at different locations. The HCN content was greater in plants grown under drought conditions, than in those grown under more favourable moisture conditions. The leaves contained much more HCN than the stems. Curing decreased the HCN content of the sorghum.

Varietal differences were found in regard to HCN content, Rancher containing the least amount of the varieties tested.

Under greenhouse conditions, wilted plants of Rancher 8 inches high contained a smaller amount of HCN than plants of Early Amber of the same height. This difference disappeared as the plants matured. The toxicity of both varieties decreased with maturity.

Frost damage increased the HCN content in second growth of these varieties, but not in the first growth in the heading stage.

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ERRATUM

In the article entitled "Relative Potencies for Poultry of the Canadian Standard Reference Cod Liver Oil and the British Provisional Standard Preparation of Vitamin D_3" by I. Motzok, D. C. Hill and S. J. Slinger, March 1947 issue of "Scientific Agriculture" (Vol. 27, No. 3), page 106, second line of second last paragraph, and page 108, seventh line of summary, the word "tibiae" should be "tarso-metatarsi".

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